PREHISTORIC LANDSCAPE USE IN THE CENTRAL ALASKA RANGE

A Dissertation

by

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ABSTRACT

The mountainous upland landscapes of central Alaska play an important role in understanding key issues in Beringian archaeology, including human adaptation to new landscapes, changes in landscape use in response to environmental change, and factors driving lithic assemblage variability. There are three important research issues concerning hunter-gatherer upland use: (1) the timing of upland settlement, (2) changes in upland land-use strategies over time, and (3) the influence of upland activities on central Alaskan lithic assemblage variability. This study addresses these topics through (1) pollen analysis of a peat core from the upper Susitna River basin to provide local environmental context for human adaptation, (2) locating and investigating previously unknown archaeological sites in the upper Susitna basin, (3) archaeological testing of new and previously recorded sites in the upper Susitna basin, and (4) analysis of lithic assemblages from these sites as well as previously documented sites in the upper Susitna basin.

This study found that humans first occupied the upper Susitna basin in the early Holocene, by 11,000-10,500 cal BP. This is at least 2000 years after the end of full glacial conditions, and 1000 years after first evidence of landscape recovery. Following the initial occupation, there is evidence for human use of the upper Susitna basin from the early through late Holocene. Initial early Holocene use appears to have been ephemeral, consisting of short-term logistical forays

by mobile hunter-gatherers provisioned with lithic raw materials necessary for subsistence activities. Human activity in the upper Susitna basin intensified in the middle and late Holocene as modern vegetation patterns became established, when hunter-gatherers occupied the upper Susitna basin in a low-mobility land-use system, provisioning upland base camps with the lithic raw material necessary for subsistence activities, and foraying out to logistical resource extraction camps in the uplands of the upper Susitna basin.

There are preliminary indications that vegetation may have been affected by Holocene tephra fall, and evidence for a hiatus in human occupation of the upper Susitna region during the middle Holocene, but it is unclear whether this was directly related to tephra deposition, or broader climate instability during the Neoglacial Period. A subtle shift in site location in the late Holocene may be tied to changing caribou hunting techniques. Throughout the Holocene, bifacial hunting weaponry was favored for upland subsistence activities.

DEDICATION

For my parents, Pat and John.

ACKNOWLEDGEMENTS

I am deeply indebted to Ahtna Incorporated, the Ahtna Inc. Board of Directors, and the Cantwell Native Village Council for giving me permission to include test excavation data from Butte Creek 1 (HEA-499) and Snodgrass Lake 1 (HEA-500) in this dissertation. Butte Creek 1 and Snodgrass Lake 1 are located on a federally managed land parcel selected by Ahtna Inc. to be conveyed to Ahtna private land holdings sometime in the future. Ahtna Inc. identified this land parcel as historically important because Ahtna oral tradition indicates that traditional caribou hunting methods were developed here, and within the parcel is the gravesite of Western Ahtna Chief Tyone. During the course of my dissertation research I found out that I had inadvertently conducted unpermitted test excavations on this land parcel. As a result of consultation with Ahtna Inc. after this mistake was discovered, I agreed to provide an explanation in my dissertation of how I ended up conducting unauthorized excavations on Ahtna-selected land, and what I learned from the process, in an effort to educate other archaeologists and avoid future mistakes of this nature.

I conducted my dissertation field research in the upper Susitna basin under permit from the Alaska State Office of History and Archaeology (OHA). The OHA permit gave me permission to conduct archaeological survey and testing on land parcels falling into the category of “state general lands”. Prior to submitting my permit application, I conducted research on land-status

designations in the upper Susitna basin using the State of Alaska Department of Natural Resources (DNR) online mapping system. While conducting this research, I mistakenly came under the impression that state-general lands included three categories of land identified in the DNR mapping system: state patent, state temporarily-approved, and state-selected land parcels. I requested permission from the OHA to work in the area around Snodgrass Lake and Butte Creek, an area identified as state-selected land in the DNR mapping system. Within this section of land, I conducted minimal test excavations at Butte Creek 1 (two 1 x 50 cm test units) and Snodgrass Lake 1 (two 50 cm^2 test units).

In the spring of 2014 I presented the results of my field research at the annual Alaska Anthropological Association meeting. In attendance during my presentation was John Jangala, the Bureau of Land Management (BLM) Glennallen Field Office Archaeologist responsible for managing cultural resources on BLM-managed land in the upper Susitna basin. Following my presentation, John notified me that the BLM, not the OHA, managed cultural resources on state-selected land, so the permit issued by the OHA did not give me permission to excavate archaeological sites on state-selected land. Compounding this error, although the parcel of land containing Snodgrass Lake 1 and Butte Creek 1 was identified as state-selected land in the DNR mapping system, it had been registered as native-selected with the BLM based on the Ahtna claim of historical significance. Unauthorized excavation of archaeological sites on native-selected land is a serious issue. The BLM requires extensive consultation with native corporations before any research of this type will even be considered, and typically does not approve archaeological research on native-selected land managed by the BLM.

As the co-principal investigator and field supervisor and for this project, it was my responsibility to make sure that field research was conducted only in areas covered under the OHA permit, and I failed to do that. I want to be very clear that this is a serious mistake that I made. I sincerely regret my misunderstanding of the Alaska land-status system that led to unauthorized excavations on Ahtna-selected land. While test excavations did not impact Chief Tyone’s gravesite in any way; HEA-499 is 250 meters from the gravesite, and HEA-500 is 300 meters from the gravesite; the general area of the gravesite is of major importance to Ahtna and the descendants of Chief Tyone.

As a result of the consultation process that followed this mistake, I have a better appreciation for the importance of communicating with Native groups in advance of field research, regardless of whether it is required as part of the permitting process. I would recommend consultation with Native groups that have traditional ties to lands where research is being proposed well in advance of research. I would also caution that land status in large portions of Alaska is still largely undetermined, and changes frequently due to land conveyance. As a precautionary measure, both State and Federal land managers should be consulted when determining current and accurate land status.

I would like to thank my committee chair, Dr. Ted Goebel, for guidance over the years, and for supporting me and providing me with opportunities to grow as a researcher. I would also like to thank my committee members, Dr. Mike Waters, Dr. Kelly Graf, Dr. Fred Smeins, and Dr. Nancy Bigelow, for their guidance throughout this research. I would like to extend my gratitude to the granting agencies that made this research possible: National Science Foundation Arctic Social Sciences, Sigma Xi, Arctic Institute of North America, Frison Institute Patrick Orion Mullen Award, Elfrieda Frank Foundation, Center for the Study of the First Americans Roy Shlemon Scholarship, Texas A&M University Department of Anthropology, and the Texas A&M University College of Liberal Arts. I would also like to thank the staff at the University of Alaska Museum of the North for allowing me access to museum collections and providing me with obsidian PXRF analysis data.

My family has always encouraged and supported my endeavors; my mother Pat and father John provided me with a solid foundation, encouraged an inquisitive mind, and took our family across the country to explore mountains, forests, and seas. My sisters, Maureen and Sharon, are gifted scientists and teachers, and I have always appreciated my conversations with them and look forward to many years of the same. I need to thank my writing buddy, Biscuit, for helping me to take my mind off of things. Finally, I would like to thank Nanda, for her love and support throughout this long process, and for helping me keep focused on the big picture. I look forward to our life and careers together.

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CHAPTER I

INTRODUCTION

The mountainous upland landscapes of central Alaska play an important role in understanding key issues in Beringian archaeology, including human adaptation to new landscapes, changes in landscape use in response to environmental change, and factors driving lithic assemblage variability. Adapting to environmental shifts during the late Pleistocene and Holocene required unique behavioral and corresponding lithic technological adjustments. Humans occupied the Tanana lowlands of central Alaska as early as 14,000 calendar years ago (cal BP) (Holmes 2001), possibly as shrub-tundra vegetation spread into the region during the late glacial (Hoffecker and Elias 2007). The adjacent uplands of the central Alaska Range do not appear to have been occupied until much later, despite deglaciation as early as 21-17,000 cal BP (Briner and Kaufman 2008; Dortch 2006; Dortch et al. 2010; Holmes et al. 2010). In fact, there is little evidence for sustained use of upland resources until the early-mid Holocene (Graf and Bigelow 2011; Mason et al. 2001; Potter 2008a, 2008c).

Eventual uplands occupation has been explained by two models, the *land-use strategy model* and the *seasonal-landscape-use model*. The *land-use strategy model* hypothesizes that the uplands did not play an important role in hunter-gatherer subsistence activities until after 6000 cal BP, when there was a shift to a logistically mobile settlement system utilizing seasonally available upland resources (Potter 2008a, 2008c). The *seasonal-landscape-use model* attributes variability in projectile technology (i.e. bifacial vs. inset-microblade) to shifting technological-organization strategies, tied to seasonal subsistence activities and lithic raw-material availability in upland and lowland landscapes (Potter 2011; Wygal 2009, 2010). Testing these models has been inconclusive because our knowledge of prehistoric upland use in central Alaska is limited, as previous studies have focused on evidence from the lowlands (Holmes 2001, Powers and Hoffecker 1989; Potter 2005). This leaves three important research issues concerning hunter-gatherer upland use: (1) the timing of upland settlement, (2) changes in upland land-use strategies over time, and (3) the influence of upland activities on central Alaskan lithic assemblage variability.

This study addresses these topics by (1) a preliminary pollen analysis of a peat core from the upper Susitna River basin to provide local environmental context for human adaptation, (2) locating and investigating previously unknown archaeological sites in the upper Susitna basin, (3) archaeological testing of new and previously recorded sites in the upper Susitna basin, and (4) analysis of lithic assemblages from these sites as well as previously excavated sites in the upper Susitna basin. These data are used to assess the nature of upland landscape use throughout prehistory, provide a comprehensive characterization of upland lithic technological and settlement organization, and inform on changes in hunter-gatherer adaptations to changing paleoenvironments through time.

Defining the Uplands

Physical geography is a primary factor in conditioning ecological patterns in central Alaska (Gallant et al. 1995; Potter 2008a, 2011). To establish the context for human use of upland landscapes, this study utilizes the “Ecoregions of Alaska” concept, combining a comprehensive suite of environmental characteristics to delineate the upland and lowland environments of central Alaska (Gallant et al. 1995; Nowacki et al. 2001). Of primary importance to this discussion is the Alaska Range Ecoregion covering the mountainous Alaska Range (Figure 1), consisting of rugged mountain ridges separated by broad valleys. In this area, vegetation is predominantly dwarf-scrub communities, with some low or tall scrub communities on moist-to-mesic, protected sites, and open forest and woodlands on some valleys and lower hill slopes (Gallant et al. 1995; Nowacki et al. 2001).

The boundary of the Alaska Range Ecoregion and interior forested ecoregions to the north and Cook Inlet Ecoregion to the south generally follows a 600-masl contour line. To the southeast, the ecoregion boundary generally follows a 900-masl contour separating it from the Copper Plateau Ecoregion (Gallant et al. 1995; Nowacki et al. 2001). These delineations are somewhat diffuse; ecological attributes in mountainous areas typically occur gradually, associated with an environmental gradient (Gallant et al. 1995; Körner 2007; Nowacki et al. 2001). Accordingly, Gallant et al. (1995) identified transitional areas at the boundaries of the Alaska Range Ecoregion; the most important of these for this discussion is the foothills region north of the Alaska Range, between 600 and 500 masl in the Nenana River drainage, exhibiting characteristics of both upland and lowland environments.

Using this ecoregion framework, this study focuses on the paleoenvironmental and archaeological records of the upland Alaska Range Ecoregion, and addresses four important issues in Alaskan prehistory: (1) timing and character of paleoenvironmental change from 14,000-1000 cal BP, (2) timing of upland settlement, (3) changes in upland land-use strategies over time, and (4) influence of upland activities on central Alaskan lithic-assemblage variability.

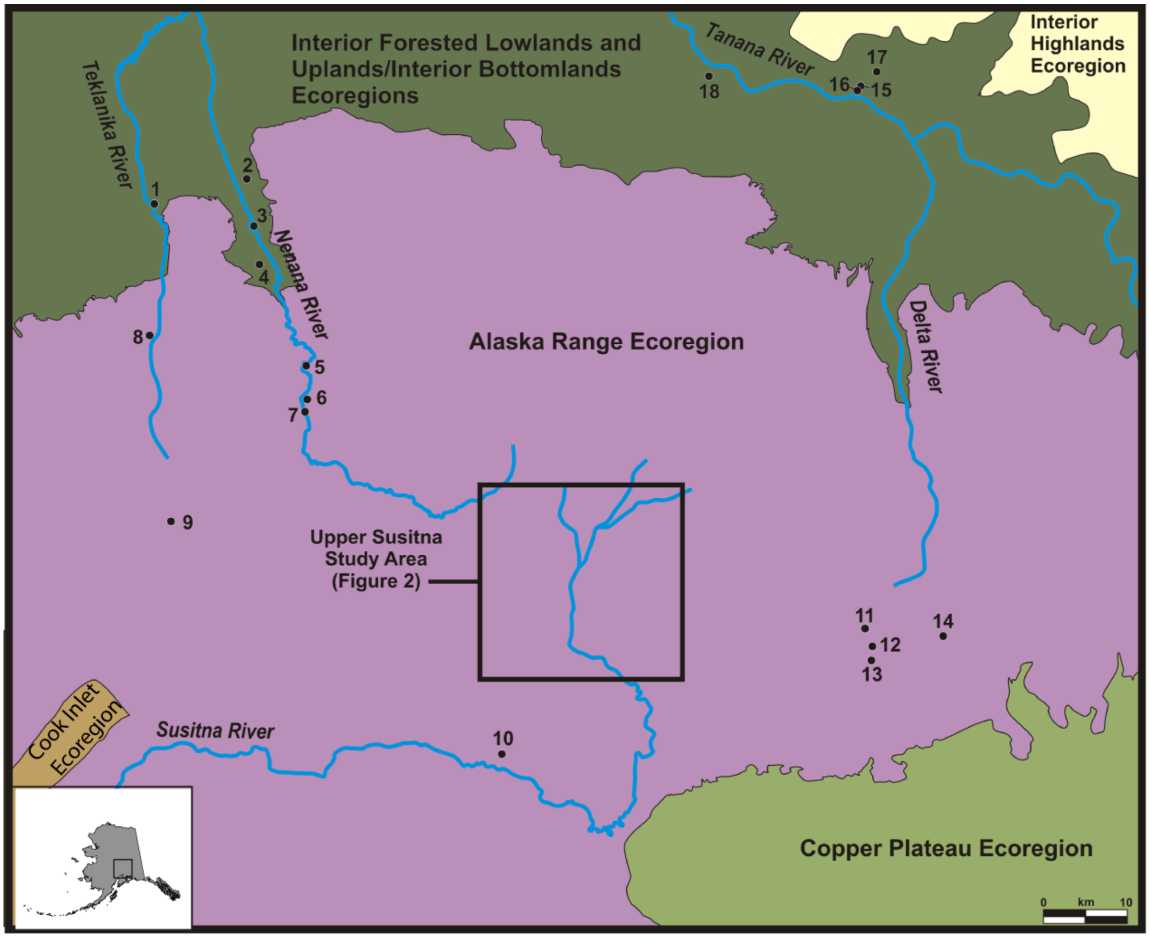

Figure 1. Map of central Alaska Range showing Alaska Range Ecoregion, upper Susitna study area, and locations of sites discussed in text: 1, Owl Ridge; 2, Moose Creek; 3, Walker Road; 4, Dry Creek; 5, Windmill Lake; 6, Eroadaway; 7, Carlo Creek; 8, Teklanika West; 9, Bull River II; 10, Jay Creek Ridge; 11, Landmark Gap Trail; 12, Phipps, Whitmore Ridge, Rock Creek section, Long Tangle Lake; 13, Sparks Point; 14, Tenmile Lake; 15, Mead; 16, Broken Mammoth; 17, Swan Point; 18, Upward Sun River.

Paleoenvironmental Record of Central Alaska

Following full glaciation of the central Alaska Range during the Last Glacial Maximum (22,000 cal BP), glacial ice sheets in central Alaska retreated rapidly, beginning as early as 21-17,000 cal BP (Briner and Kaufman 2008; Dortch 2006, Dortch et al. 2010). Regional pollen records suggest that the lowland central Alaskan landscape was comprised of herb- and forb-dominated tundra prior to 14,000 cal BP, and shifted quickly after 14,000 cal BP to *Betula* (birch) shrub-tundra. By 12,800 cal BP, there was an increase in herbaceous taxa in some locations associated with cooling and drying of the Younger Dryas (12,800-11,700 cal BP), but shrub tundra persisted in other locations. From approximately 11,000-9000 cal BP, warming climate of central Alaska resulted in expansion of *Populus* (aspen) lowland parkland, followed by the spread of *Picea* (spruce) lowland forest after 10,000 cal BP Vegetation patterns in lowland central Alaska were broadly similar to modern vegetation by approximately 7000 cal BP (Anderson et al. 2004; Bigelow and Edwards 2001; Bigelow and Powers 2001).

In general, middle Holocene and late Holocene climate in Alaska was cooler and wetter than that of the early Holocene (Anderson and Brubaker 1994; Anderson et al. 2003; Bigelow and Edwards 2001; Bigelow and Powers 2001). The Holocene glacial record indicates that the middle and late Holocene were times of climatic fluctuations in central Alaska, with temperatures oscillating between cool and warm with the onset of the Neoglacial Period (NP) approximately 4000-2000 cal BP, followed by warming in the Medieval Warm Period (MWP) approximately1100-700 cal BP. Temperatures cooled again during the Little Ice Age (LIA) approximately 700-200 cal BP, before warming to modern levels (Barclay et al. 2009; Calkin 1988; Hu et al. 2006; Loso 2009; Mann et al. 1998; Mason and Begét 1991). Periods of cooling during the NP and LIA are correlated with heightened wind intensity and increased sediment deposition in the Nenana Valley, indicating the significant effect that climate fluctuations had on regional landscapes (Bigelow 1991; Mason and Begét 1991; Powers and Hoffecker 1989).

There is little high-resolution pollen evidence available to document late Pleistocene (LP) and early Holocene (EH) vegetation change in the uplands. Following peak glaciation during the Last Glacial Maximum (22,000 cal BP) glacial ice sheets in central Alaska retreated rapidly, beginning as early as 21,000-17,000 cal BP, and culminating with the end of full-glacial conditions in central Alaska by 12,000 cal BP (Briner and Kaufman 2008; Dortch et al. 2010). Pollen data from Windmill Lake (640 masl) along the upper Nenana River (Figure 1) provide the most reliable record of upland vegetation in the central Alaska Range (Bigelow and Edwards 2001), indicating there was a late Pleistocene herb- and forb-dominated tundra that shifted to a mosaic of *Betula* shrub-tundra and herb- and forb-dominated tundra around 13,600 cal BP

Toward the end of the Younger Dryas, there was a subtle shift back towards herb- and forb-dominated tundra, probably associated with cooler and dryer conditions. *Populus* was present by 10,800 cal BP and *Picea* was present by 9300 cal BP. *Picea* and *Alnus* (alder) were well established by 7400 cal BP, and the spruce forest was probably stabilized at modern treeline by this time. The vegetation at Windmill Lake 7400 cal BP was probably very similar to that of the present day, primarily consisting of *Picea* and *Betula* trees and shrubs, suggesting that vegetation in the region remained relatively stable throughout the MH and LH (Bigelow and Edwards 2001).

This reconstruction, however, is at odds with pollen-core data from two upland locations – the Rock Creek section in the Tangle Lakes at 860 masl (Schweger 1981) and Tenmile Lake at 1000 masl (Anderson et al. 1994) (Figure 1). Both display earlier than expected appearances of *Betula*, *Alnus* and *Picea* (prior to approximately 10,300 cal BP at both locations), interpreted by some to be the result of long-distance transport of lowland pollen taxa, as well as coarse pollen and radiocarbon sampling intervals, which resulted in low-resolution paleoenvironmental reconstructions at these locations (Bigelow and Edwards 2001; Bigelow and Powers 2001; Graf and Bigelow 2011).

Pollen cores from Swampbuggy Lake (813 masl) and Nutella Lake (931 masl) in the upper Susitna basin (Figure 2) provide evidence that *Picea* was established by 7600 cal BP (Rohr 2001); while pollen core data from Long Tangle Lake (~860 masl) (Figure 1) indicate that scattered spruce were in the uplands by 5200 cal BP, but were not well established until ~3800 cal BP (Ager and Sims 1981). Long-distance transport of lowland taxa pollen into these upland lakes, however, could have masked the local vegetation signature (Bigelow and Powers 2001; Seppä and Hicks 2006). What is needed is a high-resolution, local pollen record for the central Alaska Range uplands. The lack of such a record leaves unanswered questions about paleoenvironmental change. Does the pollen record at Windmill Lake represent the vegetation history for the entire uplands region of central Alaska? If not, when precisely did modern vegetation patterns become established in the study area of the upper Susitna basin of the south-central Alaska Range? To resolve these problems, this dissertation developed a local vegetation history based on cores drawn from peat bogs in the upper Susitna study area.

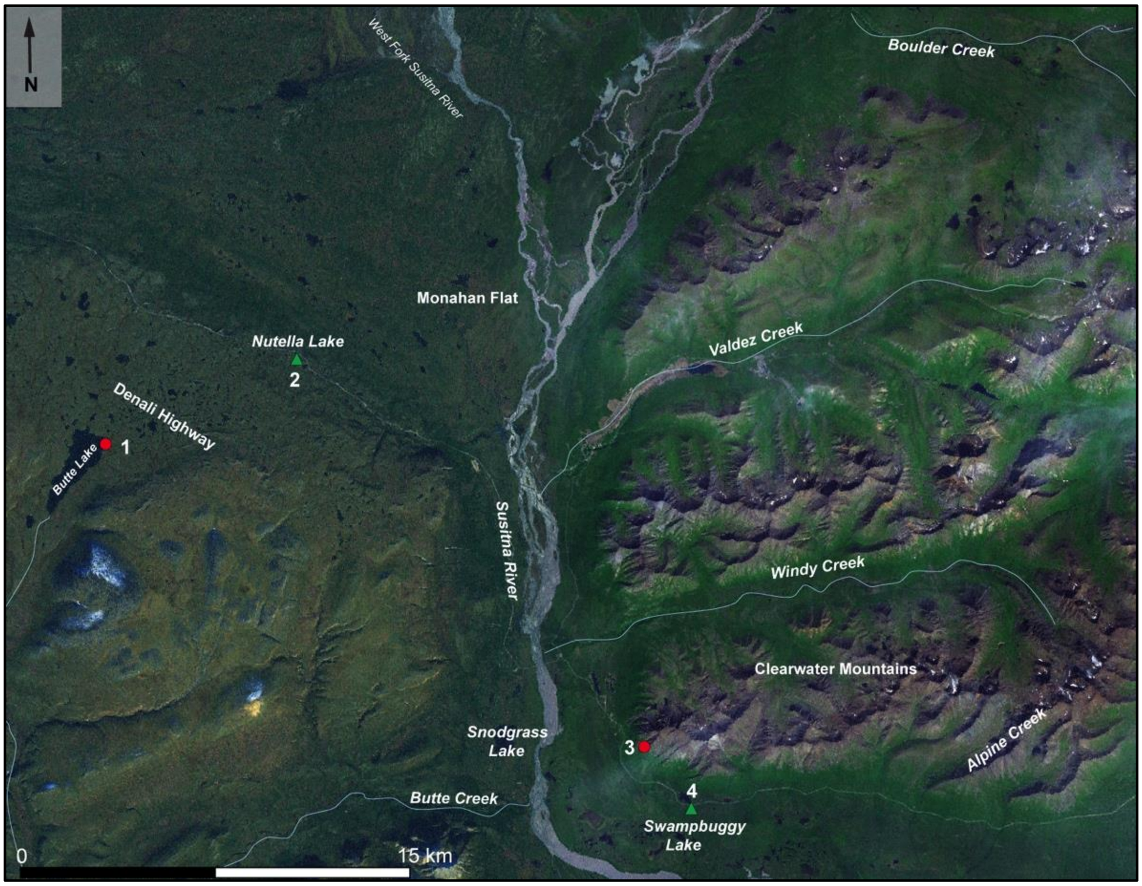

Figure 2. Upper Susitna study area and sites mentioned in text: 1, Butte Lake; 2, Nutella Lake; 3, Ratekin; 4, Swampbuggy Lake.

Human Settlement of the Central Alaska Range

More than 163 archaeological sites dating to the LP and EH have been recorded in central Alaska, but few of these are located in the Alaska Range uplands (Potter 2008a, 2008c). The earliest evidence for human occupation of central Alaska comes from the Tanana Valley lowlands (Figure 1) where at Swan Point cultural material has been dated to 14,200 cal BP (Holmes 2001, 2011; Potter et al. 2014). Nearby, Broken Mammoth, Mead, Upward Sun River, and McDonald Creek provide further early evidence of humans in the Tanana Valley lowlands between about 14,000-13,200 cal BP (Goebel et al. 2014; Holmes 2001; Potter et al. 2011). In the neighboring foothills of the Nenana and Teklanika valleys, the earliest evidence for humans is at Dry Creek, Walker Road, Owl Ridge, and Moose Creek, all dating to 13,500-13,000 cal BP (Graf et al. 2015; Graf and Bigelow 2011; Pearson 1999; Powers and Hoffecker 1989). Contrastingly, the earliest evidence for human occupation in the Alaska Range is at Eroadaway (12,750 cal BP) and Bull River II (12,460 cal BP) (Holmes et al. 2010; Wygal 2009, 2010).

Researchers have explained the lowland-upland chronological disparity in earliest occupations ecologically. The *shrub-tundra settlement model* links the first appearance of humans in Beringia to the spread of the shrub tundra, as climate ameliorated during the Bølling/Allerød interstadial (14,600-12,800 cal BP) (Bigelow 1997; Bigelow and Powers 2001; Hoffecker and Elias 2007). A shrub-tundra environment would have provided reliably located faunal resources, such as *Bison* sp. (bison) and *Cervus* sp. (elk) (Bigelow 1997; Bigelow and Powers 2001), and accordingly these species appear frequently in early archaeological sites (Powers and Hoffecker 1989; Yesner 2001). In addition, shrub-tundra vegetation would have provided fuel in the form of woody shrub birch and willow (Bigelow 1997; Guthrie 1995; Hoffecker and Elias 2007). This model is supported by the co-occurrence of the earliest archaeological sites with paleoenvironmental evidence of the spread of shrub-tundra in the lowlands (Tanana Valley sites) then foothills (Nenana and Teklanika valley sites) of central Alaska (Bigelow and Powers 2001; Hoffecker and Elias 2007).

The shrub-tundra settlement model, however, may not account for human activity in the Alaska Range Ecoregion. Bull River II is in an alpine-tundra setting today, and it likely was as well when humans appeared there 12,460 cal BP (Wygal 2009, 2010). In addition, Schweger (1981) reports shrub tundra at the Rock Creek section in the Tangle Lakes by 14,000 (although this date has a standard deviation of ± 1000), yet the earliest evidence of upland use there is 2000 years later at the Phipps site (~12,000 cal BP) (West et al. 1996a). The coarse chronology for the Rock Creek section illustrates the need for a precisely dated, localized paleoenvironmental record in the south Alaska Range to assess the applicability of the shrub-tundra model in the uplands. These anomalies beg the questions: Is the temporal gap in settlement between the lowlands and uplands real, or a product of sampling? When precisely did humans first begin using the uplands? If initial colonizers preferentially utilized shrub-tundra landscapes, was this a factor limiting early use of upland landscapes?

Upland Land-Use Strategies

Following the earliest evidence of human use of the Alaska Range Ecoregion at Eroadaway and Bull River II, there is evidence of upland use at the Tangle Lakes sites of Phipps, Whitmore Ridge, and Sparks Point, all dating between 12,000 and 10,300 cal BP (West et al. 1996a, 1996b, 1996c), as well as in the upper Nenana valley at Carlo Creek (11,300 cal BP) (Bowers and Reuther 2008). Despite this, there is no evidence of sustained use of the uplands during the LP/EH; instead only sites reflecting short-term, abbreviated occupations have been found (Graf and Bigelow 2011; Mason et al. 2001).

Potter (2008a, 2008c) analyzed site-location data in central Alaska and developed a *land-use strategy model* of human settlement, stating that hunter-gatherers prior to 6000 cal BP concentrated subsistence activities in the lowlands, maintaining a generalized economy targeting bison, wapiti, and birds year-round, from short-term, open-air camps. Use of the uplands during this time consisted of limited seasonal forays (Potter et al. 2014). Demographically, Potter (2008a, 2008b) hypothesized that the spread of spruce forests in the lowlands 10,000-9000 cal BP was accompanied by a population decline throughout central Alaska, potentially associated with lower carrying capacities (see also Bever 2006).

Beginning in the middle Holocene (MH) ~6000 cal BP, Potter's (2008a, 2008b, 2008c) data suggest a gradual increase in population as hunter-gatherers successfully adjusted to forested conditions by shifting to a logistically mobile settlement system, focusing on seasonal resources like caribou (*Rangifer tarandus*) and fish, and increasingly using the uplands. During the late Holocene (LH) (~1200 cal BP), Potter hypothesizes a further shift to seasonally-specific residential habitation sites and continuing logistical mobility, evidenced by the presence of house pits and cache pits at sites dating to this time period (Potter 2008a, 2008b).

This shift seems to have included sites in the uplands as well. At Butte Lake (Figure 2), component 3 yielded a house pit, cache pits, fire-cracked rock, and caribou-bone-processing features assigned to the LH (Betts 1987; Wendt 2013). While from an undated context, "cooking stones" also have been recovered at the Ratekin site (Figure 2), indicating a more permanent residence (Skarland and Keim 1958).

There is evidence contradicting Potter's pre-6000 cal BP land-use strategy model. Wygal (2009) points to the early age of Bull River II and ethnographic evidence for the importance of upland hunting to hypothesize that LP/EH upland landscapes played a significant role in early central Alaskan human subsistence, providing early habitat for caribou and Dall sheep (*Ovis* *dalli*). He argues that humans forayed into the uplands to procure these resources, but that we do not yet know the extent of LP/EH upland use because sites representing this activity are undated or undiscovered. Mason et al. (2001) further argue that the majority of occupations in central Alaska during the Milankovitch thermal maximum (10,000-9000 cal BP) occur at higher elevations, as part of the spread of mobile bands of hunters procuring resources (i.e., sheep) in the uplands, and Graf and Bigelow (2011) argue that the Alaska Range uplands were repeatedly utilized during the Younger Dryas. Similarly, Yesner (2001) notes the variety of faunal taxa represented at the Broken Mammoth site as evidence for utilization of various microenvironments during the LP/EH, including upland procurement of marmot (*Marmota flavescens)*, Dall sheep and possibly caribou.

Further contradicting Potter (2008a, 2008c), there is evidence of changing settlement systems during the LP/EH, from initial LP colonizing hunter-gatherers with low mobility, to highly mobile, possibly logistically oriented EH hunter-gatherers (Graf and Goebel 2009; Graf and Bigelow 2011). Demographically, Mason and Bigelow (2008) suggest that the apparent population collapse associated with the spread of spruce forest may be an artifact of taphonomic loss, as geomorphic processes during the EH would have destroyed or deeply buried archaeological sites.

There is also evidence contradicting Potter's post-6000-cal-BP landscape-use strategy model. Mason and Bigelow (2008) question the correlation of spreading populations adapted to the spruce forest, as many sites during this period occur in the boreal/tundra ecotone or shrub tundra vegetation zone (Esdale 2008). Mason and Bigelow (2008) also point out the lack of storage features during the MH, contradicting Potter's hypothesized shift towards a logistically mobile settlement strategy. Another issue is human response to volcanic eruptions. VanderHoek (2009) provides evidence that volcanic effects, including ash fall, can have a negative impact on fauna and flora, subsequently affecting human population demographics. There is evidence of significant MH/LH ash fall in the central Alaska Range several times during the Holocene (Begét et al. 1991; Dixon and Smith 1990; Wallace et al. 2014), indicating that this may have played a part in landscape evolution and human settlement.

These contrasting interpretations of land-use strategies leave many questions unanswered. Was there a uniform LP/EH residentially mobile settlement system as predicted in the *land-use strategy model*, with infrequent or no use of upland landscapes? Or did LP/EH hunter-gatherers regularly rely on upland resources? Is there a recognizable population decrease 10,000-9000 cal BP, followed by sustained settlement linked to the spread of spruce boreal forest 6000 cal BP? Is there a shift toward logistical forays into the uplands associated with the spread of spruce forest in the MH/LH? What was the nature of upland use throughout prehistory – was it occasional/seasonal hunting forays or more permanent settlements? To address these questions, this study conducted an intensive survey of a well-defined study area in the uplands of the central Alaska Range, to document, test, and date archaeological sites, and establish the record of prehistoric human occupation in the uplands.

Central Alaskan Lithic Assemblage Variability

Central Alaska has a unique and diverse archaeological record, with significant spatial/temporal variability in lithic assemblages highlighted by preferential use of bifacial versus inset-microblade projectile technology (Goebel and Buvit 2011; Hoffecker and Elias 2007). Early research focused on temporal differences in these technologies, attributing variability to different cultural groups living in Alaska at different times (Dixon 1985; Goebel et al. 1991; Hoffecker et al. 1993; Pearson 1999; Powers and Hoffecker 1989); however, subsequent research has revealed a more complex picture (Holmes 1996, 2001, 2011; Holmes et al. 1996; Potter 2008a), attributing variability to different behaviors (Potter 2005, 2008a, 2008b, 2008c, 2011; Potter et al. 2014; Rasic and Andrefsky 2001; Robinson 2008; Wygal 2009, 2010).

The most intriguing behavioral explanation is the *seasonal landscape-use model*, which proposes that technological choices were conditioned by seasonal subsistence activities in upland and lowland landscapes, as well as lithic raw-material availability (Potter 2005, 2008c, 2011; Wygal 2009, 2010). Wygal (2009; 2010) hypothesizes that inset-microblade technology may have been more reliable and more effectively conserved raw material than bifacial technology during winter, when stone became brittle and hard to find under snow cover, and lowland bison (*Bison* sp.), moose (*Alces alces*), and wapiti (*Cervus canadensis*) were procured. In contrast, bifacial points may have been preferred for caribou and sheep hunting during summer, when raw material was readily available and there was less risk of cold-failure (e.g., Elston and Brantingham 2002, Flenniken 1987). Potter (2008c, 2011) hypothesizes that inset-microblade points were used as thrusting spears to hunt lowland bison, moose, and wapiti in the fall-winter-spring, while bifacial points were preferred for hunting caribou and sheep in the uplands in the summer. Potter (2008c) attributes the emergence of various new bifacial point forms in the MH to a shift in landscape use highlighted by expanded use of the uplands, in particular caribou hunting.

The seasonal landscape-use model rests on the idea that upland settings were likely uninhabitable in the winter months, and ethnographic evidence that contact-period Native Alaskan Dena'ina occupied winter camps in the lowlands, where many animal species congregate in protected valleys (MacDonald and Cook 2009; VanderHoek et al. 2007a; Wygal 2009). Additionally, modern studies of Alaskan fauna indicate that many species move into the cooler uplands during summer, especially caribou, which congregate on upland ice patches. Corresponding to this, archaeological survey of ice patches in the broader region has located prehistoric hunting implements (Dixon et al. 2005; Hare et al. 2004; Reckin 2011; VanderHoek et al. 2007a, 2007b). Variation in subsistence/settlement system, mobility, and seasonal task scheduling certainly impacted human technologies, therefore understanding tools and toolkits within the adaptive system in which they occur will lead to a more robust explanation of assemblage variability (Goebel and Buvit 2011; Potter 2005, 2008a, 2008c).

The seasonal-landscape-use model is testable: there is an expectation that upland sites should be dominated by bifacial technology utilizing local raw-material, while lowland sites should be dominated by microblade technology utilizing exotic raw material (Potter 2011; Wygal 2009). Additionally, if the uplands were used in a logistical pattern during the summer, there should be evidence of technological choices made to facilitate mobility and task scheduling, as well as evidence of task-oriented camps with low tool diversity and specialized lithic assemblages. Conversely, if uplands were used by residentially mobile groups, there should be a preponderance of base camps with high tool diversity and a multifunctional, generalized lithic assemblage (Binford 1977, 1980).

Addressing the validity of the seasonal-landscape-use model requires a regional approach incorporating evidence of prehistoric landscape use and assemblage variability from both the central Alaskan lowlands *and* uplands. As it stands now, most of the archaeological evidence we have at hand comes from research in the Tanana and Nenana lowlands and foothills, while in the uplands of the Alaska Range, few sites have been well-documented (but see Coffman 2011; West et al. 1996a, 1996b, 1996c; Wygal 2009, 2010). How did upland subsistence activities condition lithic assemblages in the LP/EH? To fully evaluate the seasonal landscape-use-model, more upland sites need to be documented. To this end, this study excavated and analyzed lithic assemblages from uplands archaeological sites from a technological organization perspective, assessing lithic raw material provisioning, reduction strategies, and projectile technology in the uplands of the central Alaska Range.

Study Area

The upper Susitna River Basin lies on the southern flank of the central Alaska Range, within the upland Alaska Range Ecoregion (ARE) (Gallant et al. 1995; Nowacki et al. 2001) (Figure 1). The Ecoregions of Alaska are used in this study to characterize different landscapes, combining a comprehensive suite of environmental characteristics to delineate the upland and lowland environments of central Alaska. The Susitna River is a glacial-fed stream originating in the southern Alaska Range and braiding across the broad, glacially carved upper Susitna basin (Figure 3).

The upper Susitna basin study area is geographically diverse, including peaks as high as 1900 masl in the Clearwater and northeastern Talkeetna mountains, kettle and kame topography on the broad, glacially carved Monahan Flat, and channeled glacial outwash and braided floodplains in the Susitna River valley bottom (Kachadoorian et al. 1954; Wahrhaftig 1960, 1965).

Unconsolidated Quaternary surficial deposits dominate elevations below 1000 masl, consisting primarily of glacial drift, often reworked and deposited as alluvium along rivers and streams (Smith 1981; Smith et al. 1988; Wahrhaftig 1960, 1965).

Vegetation in the study area is primarily *Betula* shrub-tundra, with *Picea* sp. and *Populus* trees in the valley bottom, and alpine tundra in upper elevations (Figure 4). Modern treeline in the upper Susitna Basin is approximately 850 masl (Rohr 2001). Fauna in the study area today include black bear (*Ursus americanus*), brown bear (*Ursus arctos*), caribou (*Rangifer tarandus*), Dall sheep (*Ovis dalli*), moose (*Alces alces*), several species of ptarmigan (*Lagopus* sp.), snowshoe hare (*Lepus americanus*), seasonally available waterfowl, and many species of freshwater fish in lakes, rivers, and streams. The upper Susitna is an ideal laboratory for addressing upland lithic technological organization and land use because it is within the upland Alaska Range Ecoregion and it exhibits a wide range of topographic and vegetational variability, potentially reflecting the full range of upland adaptation.

Previous archaeological investigations in the study area focused primarily on cultural resource management, and there has been little research-oriented archaeological investigation in the study area (VanderHoek 2011). Two important exceptions to this are the studies of the Ratekin site (HEA-187) (Skarland and Keim 1958) and Butte Lake (HEA-189) (Figure 2) (Betts 1987; Wendt 2013). The most significant archaeological research in the broader upland Susitna basin was conducted between 1978 and 1985 in the middle Susitna basin in the Talkeetna Mountains, as part of the Susitna Hydroelectric project. This research documented 248 archaeological sites and produced important information on the glacial history, sequence of tephra deposition, and pedogenic history of the region (Dilley 1988; Dixon et al. 1985 all volumes; Dixon and Smith 1990).

Figure 3. Photograph of the upper Susitna basin study area, showing the Denali Highway in the foreground, the Susitna River in the valley bottom, and the Clearwater Mountains in the background.

Figure 4. Photograph of the upper Susitna basin study area, showing an alpine tundra landscape in the Alpine Creek valley, Clearwater Mountains.

Research Objectives

The ultimate objective of this study has been to explain human adaptation to upland environments in central Alaska from earliest settlement to less than 1000 years ago. To reach this goal, there have been four specific objectives:

(1) **To establish the local paleoenvironmental history of the upper Susitna River basin.** How did vegetation-community succession occur through the EH? When did modern vegetation communities emerge? How did tephra deposition impact local vegetation communities?

(2) **To establish the record of prehistoric human occupation of the upper Susitna basin.** When did humans first occupy the upper Susitna basin, and what was the environmental context of initial occupation? What is the sequence of archaeological site occupation through the Holocene?

(3) **To define lithic-technological activities carried out in the uplands of the central Alaska Range.** How did upland hunter-gatherers procure toolstone? Did these strategies change over time? To what extent were non-local raw materials transported into the study area? How was lithic technology organized within the uplands, and how was it affected by

environmental change? Which projectile point technologies were typically used in upland subsistence activities?

(4) **To interpret how humans utilized upland landscapes of the central Alaska Range from initial settlement to less than 1000 cal BP.** Do changes in technology provide clues to changing settlement strategies in the upper Susitna basin? How did environmental change relate to changing upland land use, for example, in relation to vegetation shifts or major ash falls? Were upland users full-time residents, or seasonal migrants from lowlands?

Organization of the Study

This dissertation represents an investigation of human use of upland landscapes from earliest settlement to the late prehistoric period. It is essentially a test of models of paleoecological change and landscape use in central Alaska. Chapter II presents an investigation of paleoecological change in the central Alaska Range through pollen, plant macrofossil, and sedimentary analysis of peat cores from the upper Susitna River basin. The goal of this analysis was to identify changes in sedimentation, vegetation, and available moisture in the study area, and relate these to Holocene climate shifts and ecological disturbance from Holocene volcanic tephra fall.

Chapter III presents geomorphic, stratigraphic, tephrochronological, and chronological data from the upper Susitna basin. The goal of this research was to create a model of landscape change and record of human use for the upper Susitna study area, to assess when and how prehistoric humans used this landscape, and how human adaptive strategies in the study area changed in response to late Pleistocene and Holocene climate change, and in response to ecosystem disturbance by tephra fall.

Chapter IV presents lithic assemblages from ten cultural components at eight Holocene-aged archaeological sites in the upper Susitna basin. The goal of this research was to investigate hunter-gatherer lithic technological organization and land-use strategies in the uplands of the central Alaska Range, assess how these strategies changed from the early Holocene through the late-prehistoric period, and infer how shifts in lithic technological organization and land-use are tied to changing environments and economies. A second goal was to assess how lithic subsistence activities on upland landscapes conditioned lithic assemblage variability. Chapter V returns to the research objectives and models detailed above, and offers a concluding analysis of the newly presented paleoecological, geomorphological, and archaeological records for the upper Susitna basin.

CHAPTER II

PALEOENVIRONMENTAL RECORD OF THE UPPER SUSITNA RIVER BASIN: A FIRST LOOK

The Holocene paleoecological record in the uplands of the central Alaska Range is understudied. Previous paleoecological research in the region has focused on late Pleistocene and earliest Holocene paleoenvironmental reconstruction, and study sites have been primarily located in the lowlands of central Alaska (e.g., Anderson et al. 2003; Bigelow and Powers 2001; Edwards et al. 2000; but see Bigelow and Edwards 2001; Rohr 2001). In addition, methodological issues have hampered previous upland paleoecological research, resulting in low-resolution paleoecological data (Bigelow and Powers 2001).

The current level of research limits our understanding of Holocene ecological changes in marginal upland environments of central Alaska. There is evidence for Holocene climatic shifts (e.g., Neoglacial Period, Little Ice Age) that may have significantly affected uplands ecology (Calkin 1988; Hu et al. 2006; Loso 2009; Mann et al.1998; Mason and Begét 1991). Treeline is particularly affected by environmental change (MacDonald et al. 2008), and shifting treelines may have significant implications for the location of subsistence resources and human demographic shifts (Mason et al. 2001; Potter 2008c). In addition, there are several significant Holocene tephra falls documented in southcentral and central Alaska (e.g., Wallace et al. 2014), and we know very little about how such episodes affected sensitive ecological systems in the uplands. This is significant not just in central Alaska, but in high altitude ecosystems affected by tephra fall or other large-scale disturbances worldwide.

The paleoecological record of the uplands also has significant implications for understanding prehistoric human use of the central Alaska Range. The archaeological record suggests that human subsistence-settlement systems expanded to include activities in the uplands during the middle and late Holocene (Dixon et al. 1985:I; Esdale 2008; Potter 2008a, 2008b), and we know very little about upland ecological conditions that accompanied this shift.

This study assesses paleoecological change in the central Alaska Range through pollen, plant macrofossil, and sedimentary analysis of peat cores from the upland upper Susitna River basin. The goal of this analysis was to identify changes in sedimentation, vegetation, and available moisture in the study area, and relate these to Holocene climate shifts and ecological disturbance from Holocene volcanic tephra fall. Issues with core extraction and radiocarbon dating hampered this study, and as a result these goals were not fully met. Nonetheless, the preliminary results can help us address when modern vegetation patterns were established in the uplands, offer an exploratory assessment of vegetation response to tephra fall, and provide a guide for future paleoecological work in the region focusing on the research potential of pollen and macrofossil work from peat bogs, a problematic source but potentially still an important one.

Background

Paleoecological History of the Upper Susitna Basin

There is no paleoecological record for the study area prior to 7600 cal BP, but vegetation was likely analogous to that at upland Windmill Lake (640 masl) along the upper Nenana River (see Chapter I). The upper Susitna basin is slightly higher in elevation than Windmill Lake (the lowest elevations in the study area are approximately 750 masl in Monahan Flat), so the vegetation changes described at Windmill Lake may have occurred slightly later here.

The pollen, plant macrofossil, and stable isotope record from lacustrine cores collected at Swampbuggy (813 masl) and Nutella (931 masl) lakes in the upper Susitna study area (Rohr 2001) (Figure 5) indicate that between 7600 and 5700 cal BP conditions were warm and dry, with elevated carbon and $\delta^{13}C$ levels and higher percentage of *Artemisia* and *Juniperus* pollen, but with increasing moisture over time, and vegetation was shrub-heath tundra (with a pollen signature dominated by shrub tundra taxa *Betula*, *Salix*, and *Alnus*) and open forest with scattered *Picea* sp. This supports a vegetation pattern in the upper Susitna basin similar to that of today by 7600 cal BP, so Rohr's study suggests that modern vegetation patterns were established in the study area at about the same time as at Windmill Lake.

From 5700 to 1400 cal BP lower carbon and $\delta^{13}C$ levels and increased *Picea* pollen and macrofossils suggest that conditions became cooler and moist with the onset of the Neoglacial period, and spruce cover increased to form dense forest tundra at lower elevations. From 1400 to 700 cal BP elevated carbon and $\delta^{13}C$ levels suggest there were warmer, dryer intervals within an overall cooling trend, and declining *Picea* densities. From 700 to 200 cal BP lower carbon and $\delta^{13}C$ levels suggest conditions were cool and moist associated with the Little Ice Age, causing a decrease in *Picea* cover and possible lowering of treeline. After 200 cal BP conditions were initially cool, followed by a warming trend and increase in *Picea* density (Rohr 2001).

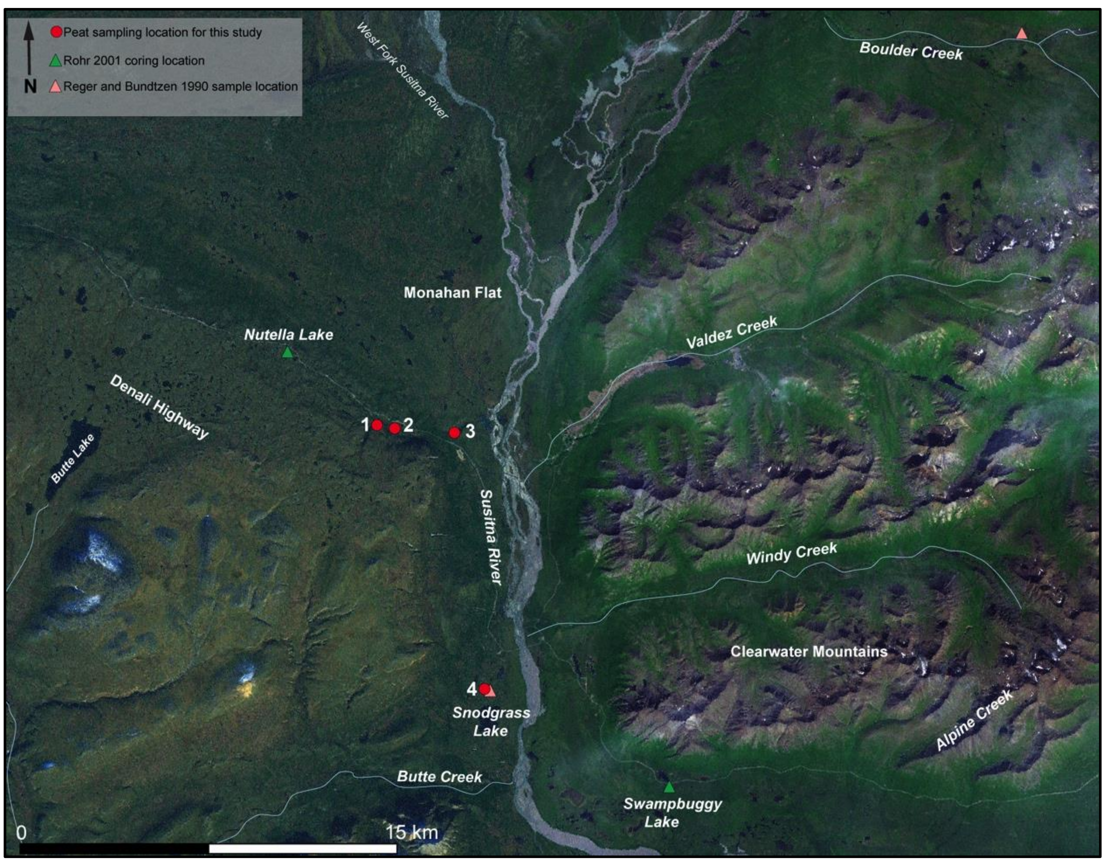

Figure 5. Map of upper Susitna study area, showing previous paleoecological research sampling locations and peat sampling locations for this study: 1, WP634; 2, WP633; 3, Susitna Dune Bog B; 4, Snodgrass Lake Site A.

The Effects of Holocene Tephra Falls

A series of Holocene tephra falls have been documented across southcentral Alaska and the central Alaska Range (Beget et al. 1991; Riehle 1985; Wallace et al. 2014). Research in the Talkeetna Mountains in southcentral Alaska documented a sequence of three tephra falls that have been correlated to tephra deposits across southcentral Alaska (Wallace et al. 2014). These were given local, informal designations: from youngest to oldest, the Devil, Watana (also known as the Cantwell ash, Jarvis Ash Bed, Jarvis Creek Ash, and Tangle Lakes Ash), and Oshetna tephras, typically separated in terrestrial settings by aeolian sedimentary units or paleosols (Beget et al. 1991; Bowers 1979; Dilley 1988; Dixon et al. 1985; Dixon and Smith 1990; Romick and Thorson 1983).

The three tephra deposits identified in the Talkeetna Mountains are thought to derive from the Hayes Volcano, the northernmost active volcano in the Aleutian-Alaskan volcanic arc, located in the northern Tordrillo Mountains in the Cook Inlet region of Alaska (Dilley 1988; Wallace et al. 2014). Between approximately 4200-3800 cal BP the Hayes Volcano produced a series of closely-spaced tephra ejections known informally as Hayes tephra set H, with an estimated composite volume of 10 km^3, representing the most significant Holocene eruptive sequence in the Cook Inlet region (Riehle 1985; Wallace et al. 2014). Hayes tephra set H deposits have been identified more than 650 km northeast of the Hayes Volcano, and are the most widespread Holocene tephras in south-central Alaska (Beget et al. 1991). Despite the broad region impacted by Hayes tephra set H, there has been little focused research investigating the effect of Hayes tephra set H or any other Hayes Volcano eruptive products on regional ecology in southcentral Alaska.

Previous research in the broader region indicates that Holocene tephra falls prompted significant ecological change and corresponding demographic shifts in hunter-gatherer populations. Mullen (2012) analyzed the frequency of radiocarbon-dated archaeological sites before and after tephra deposition to present evidence for human migration out of eastern Alaska and northwestern Canada following late Holocene volcanic eruptions that produced the White River Ash. Vanderhoek and Nelson (2007) presented evidence that middle Holocene eruptions of the Veniaminof and Aniakchak volcanoes in southwest Alaska created a substantial period of low biological productivity corresponding with human abandonment of the region for several hundred years.

Given the results of previous studies, it is possible that Holocene tephra deposition had a significant ecological impact on southcentral Alaska; however, more focused research is needed to assess ecosystem disturbance from volcanic tephra fall. This study seeks to add to our understanding of the ecosystem effects of tephra fall by focusing on the paleoecological record of the upper Susitna basin, a high-altitude, marginal ecosystem that may have been particularly susceptible to ecosystem disturbance from tephra fall.

Paleoecological Reconstruction from Peat Deposits

Pollen and plant macrofossils recovered from peat sections are typically well preserved, and can provide a more localized paleovegetation signature than pollen from lake sediments that typically contain pollen from an entire catchment basin (Faegri and Iversen 1989; Mauquoy et al. 2010; Seppä 2007). Pollen recovered from peat has been used for paleovegetation reconstruction and interpreting paleoenvironments throughout Alaska (Eisner 1991, 1997; Eisner et al. 2003; Eisner et al. 2005; Payne and Blackford 2008).

Pollen analysis can have limitations in reconstructing past vegetation; often pollen and spores are commonly only identifiable to the family or genus level. In addition, in treeless arctic and alpine settings local pollen production is often low, and despite the localized pollen signature provided by peat deposits, pollen rain from non-local taxa can be overemphasized in the pollen record (Birks and Birks 2000; Mauquoy and Van Geel 2007; Ritchie 1995). To enhance the pollen record from the upper Susitna study area, this study utilized plant macrofossil analysis to augment vegetation reconstruction. Plant macrofossil identification is often more precise than pollen identification taxonomically, and the plant macrofossil record represents *in situ* vegetation at the sampling location, allowing ecological reconstruction on a site scale, enhancing our understanding of local vegetation communities and climate conditions (Birks and Birks 2000; Mauquoy et al. 2010). However, plant macrofossils are variably produced and dispersed, so this study uses both pollen and plant macrofossils for vegetation reconstruction (Birks and Birks 2000).

Methods

Coring

Peat cores were extracted from palsas at four locations within the upper Susitna study area (Figure 5). Palsas are mounds of peat and ice that occur in bogs, typically 1-7 m high and 10-50 m in diameter (Péwé 1975:66). This study attempted to core peat deposits using three types of coring devices, a Russian peat corer, a hammer corer, and a SIPRE auger. The Russian peat corer proved ineffective at coring the typically wetter peat deposits in the study area, so the cores described here were collected using the hammer corer and SIPRE auger.

A hammer corer was used to core thawed peat, typically in the upper portion of the palsa. A SIPRE coring auger with a 3" core, driven with a motorized power head, was used to core frozen peat, typically in the lower portion of the palsa. Cores were subsampled in the field if they were icy and there was a risk of the core deforming as it melted, otherwise they were secured whole in the field and subsampled later in the lab. All cores and subsamples were transported back to Texas A&M University, where they were stored at 4°C.

Loss-On-Ignition Analysis

Loss-on-ignition (LOI) analysis was used to determine organic versus inorganic content of peat core samples. LOI methods followed standard procedures (Holliday 2004; Stein 1984; Wang et al. 2011). A 5.00-g subsample was weighed into a ceramic crucible using a digital scale. Samples were heated at 100°C for one hour in a drying oven, cooled in a desiccator for 30 minutes, and then re-weighed to the 0.01 g; this provided the dry sample weight. Samples were then placed in a cool muffle furnace, heated to 500°C, burned for two hours at 500°C, cooled in the furnace to ~150°C, placed in a desiccator for 30 minutes to cool, then weighed to the 0.01 g; this provided the non-organic carbon sample weight. The percent organic carbon in the samples was calculated following Stein (1984):

$$((\text{dry weight} - \text{weight after } 500°\text{C burn})/\text{dry weight}) * 100$$

Magnetic Susceptibility

Magnetic susceptibility (MS) was used to identify magnetized minerals in peat core samples. MS is especially effective at picking up ferric materials common in proximal tephra (Gehrels et al. 2006), and the goal of this analysis was to identify tephra deposits in the peat core. MS was measured in discrete samples on a Bartington MS 2B Dual Frequency Sensor set on low frequency. A 10-ml subsample from each core section was sealed into a 10-ml plastic square, weighed to the .00 g on a digital scale, and measured on the Barrington sensor.

Samples were measured between four and nine times each, and a mean MS reading was calculated from these measurements. The machine was calibrated periodically to ensure that the sensor was reading accurately.

MS subsamples were kept at field moisture for this analysis. Water has a negative magnetic susceptibility, so MS analysis of wet samples can result in an MS reading that is offset in the negative direction. This offset can vary depending on the moisture content of each sample (Nowaczyk 2001). However, for this study, there was limited material available for the analyses performed on each core section, so MS analysis was conducted on samples at field moisture to preserve the material for subsequent plant macrofossil analysis. MS analysis at field moisture has been used successfully in previous studies to identify tephra deposits because of the typically strong MS contrast between tephra and non-tephra horizons (e.g., Addison et al. 2010; Gehrels et al. 2006; Nowaczyk 2001).

Pollen Analysis

Pollen analysis followed conventional methods (Faegri and Iversen 1989). Peat core sections had 1 cc of peat subsampled for pollen analysis using volumetric displacement. Subsamples were treated to remove humic acids (KOH) and cellular material (acetolysis). *Lycopodium clavatum* tablets were added to each sample to calculate absolute pollen frequencies through pollen concentration and influx rates (Bryant and Hall 1993; Davis 1966; Stockmarr 1972). Although

Lycopodium clavatum is a native species in Alaskan peat deposits, the *Lycopodium clavatum* spores added to the samples underwent acetylation during tablet preparation and again during sample preparation, and were darker than the native *Lycopodium clavatum* and easily distinguishable (following Chambers et al. 2011).

Basic pollen sums were derived from counts of at least 300 pollen grains for terrestrial trees, shrubs, and herb/forbs combined, unless the sample exhibited poor pollen preservation and low concentration values. Indeterminate pollen grains were counted as an indicator of the quality of pollen preservation in the samples, and pollen concentration values were calculated to determine overall pollen preservation and pollen influx (Bryant and Hall 1993; Faegri and Iversen 1989). Pollen concentration values were calculated using the formula:

$$\frac{\text{Total indigenous pollen counted} * 18{,}533\ \textit{L. clavatum}\ \text{spores added}}{\text{Weight in grams of sample} * \#\ \text{of}\ \textit{L. clavatum}\ \text{marker spore counted}}$$

Pollen spores were viewed, counted, and photographed using light microscopy at 400x magnification. Pollen taxa were identified using the pollen reference collection at the Texas A&M University Palynology Laboratory and standard pollen keys (Faegri and Iversen 1989; Kapp 2000; McAndrews et al. 1973; Moore et al. 1991; Moriya 1976). Pollen data were diagrammed in C2 stratigraphic software (Juggins 2007), and presented as a percentage of the pollen sum for each sample. Pollen counts representing spores or non-terrestrial taxa were presented as a percent of pollen sum plus count of the specific taxa being presented. Data derived from this study were compared to regional pollen records to establish the paleoenvironmental history of the Alaska Range uplands (following Bigelow and Powers 2001).

Plant Macrofossil Analysis

Plant macrofossil processing and analysis methods were adapted from standard methods (e.g., Birks 2001, 2007; Mauquoy and Van Geel 2007; Mauquoy et al. 2010). Peat samples were measured for plant macrofossil analysis by water displacement. For most samples, 40 ml of peat was sampled for macrofossil analysis; however, sample sizes ranged from 20 ml to 50 ml depending on the amount of peat available in each core section for macrofossil analysis.

Peat subsamples were screened through 125 and 250 micron screen, and the contents of each screen were washed into a plastic bag with distilled water and stored at 4°C. Plant macrofossils were picked from the 250 fractions under 20-40x magnification. A set of ordinal values (i.e., a 0-5 scale, with 0 = absent and 5 = super-abundant) was used to estimate the abundance of insects, wood, *Sphagnum* moss, non-*Sphagnum* moss, Cladocera, chironomid head capsules, leaf fragments, charcoal, rootlets, graminoid fragments, sand, fossil oribatid mites, and tephra pumice in each sample. Picked macrofossils were identified at 40x using reference specimens collected in Alaska or obtained from the Alaska Quaternary Center at the University of Alaska Fairbanks, as well as standard atlases, including Bojňanský and Fargašová (2007), Martin and Barkley (1961), and Levesque (1988). Plant macrofossil data were diagrammed in C2 stratigraphic software (Juggins 2007), and presented as a concentration per 10 ml of sediment in a stratigraphic diagram, allowing comparison between samples of different sizes (Birks 2001, 2007).

Radiocarbon Dating

Plant macrofossils were used to date core sections. Plant macrofossils were rinsed with distilled water, examined under 10-20x magnification for contaminants, dried in an oven, weighed, packaged in glass jars, and shipped for radiocarbon analysis. Samples were dated at the National Ocean Sciences Accelerator Mass Spectrometry Facility at the Woods Hole Oceanographic Institution, University of California, Irvine Accelerator Mass Spectrometry Facility, and Beta Analytic following standard AMS radiocarbon dating techniques. Radiocarbon dates were calibrated using OxCal V4.2 with IntCal13 calibration (Bronk Ramsey 2009; Reimer et al. 2013).

Results

Sampling Locations

Four locations in the upper Susitna River valley were selected for peat coring (Figure 5). Each of the coring locations overlies Quaternary till (Smith et al. 1988). For each core extracted from these sampling locations, the lowermost core sections were subsampled for plant macrofossil analysis, and identifiable plant macrofossils were submitted for radiocarbon dating. The goal of this analysis was to establish the time depth represented by each peat core and to choose the core representing the longest paleoecological record. Descriptions of each coring location are provided below.

Susitna Dune Bog B. The peat core from the Susitna Dune Bog B (SDBB) site was collected from a palsa in a small drainage just south of a large east-west trending dune (63.18432 N, 147.56248 W, 790 masl). The SDDB core was collected using a hammer corer until frozen peat was encountered at a depth of 56 cm below surface (bs), then a SIPRE auger was used to core frozen peat to a depth of 122 cmbs. Coring halted at the contact of peat and underlying sandy gravel. The SDDB palsa has superabundant narrow-leaf Labrador tea (*Ledum decumbens*), blueberry (*Vaccinium uliginosum*), *Sphagnum* sp. moss, and common alpine azalea (*Kalima procumbens*). Vegetation in the broader sampling location consists of common shrub birch (*Betula glandulosa*) and *Betula* hybrid, willow (*Salix* spp.), few spruce (primarily white spruce [*Picea* *glauca*], but also black spruce [*Picea mariana*]), and rare low bush cranberry (*Vaccinium vitis-idaea*), fireweed (*Epilobium angustifolium*), and graminoids. Crowberry (*Empetrum nigrum*) is common in dryer areas in the bog, and Cyperaceae forms a mat in wet areas adjacent to the palsa.

The uppermost portion of the core 0-20 cmbs consisted of thawed peat with abundant *Sphagnum* sp. moss. Between 20-56 cmbs the core consisted of compressed sandy peat. Between 56-90 cmbs the core consisted of graminoid peat with sand and ice bands. Between 90-111 cmbs the core was very icy with graminoid peat, silt, and sand. The lowermost portion of the core between 111-122 cmbs consisted primarily of sandy gravel, and no plant macrofossils suitable for radiocarbon dating were recovered from this section. Plant macrofossils between 109 cmbs and 111 cmbs yielded two middle Holocene dates (5653-5470 cal BP and 3690-3576 cal BP), but the dates were stratigraphically inconsistent (Table 1). Despite the inconsistencies, these dates suggest that the SDBB core represents peat development from the middle to late Holocene.

Snodgrass Lake Site A. The peat core from Snodgrass Lake Site A (SLA) was collected from a small palsa east of a small-unnamed lake, to the north of Snodgrass Lake (63.090722 N, 147.548793 W, 773 masl). The SLA core was collected with a hammer corer to a depth of 57 cmbs; coring halted at the transition between peat and an underlying organic silt horizon because the hammer core was unable to penetrate the dense, partially-frozen sediments, and the core did not reach gravel. Vegetation on the palsa consists of abundant shrub birch and narrow-leaf Labrador tea, common blueberry, willow, and moss, and rare lichen, Cyperaceae, willow, and cloudberry (*Rubus chamaemorus*). Vegetation surrounding the palsa consists of abundant Cyperaceae and moss, few to locally common shrub birch, and few blueberry and cloudberry shrubs. The SLA core consisted of thawed peat between 0-55 cmbs and organic silt between 55-57 cmbs. The core was heavily compressed as a result of using a hammer corer. The total core length was 38 cm, despite being collected from a 57-cm deep profile. The 38-cm core was sampled in 2-cm increments starting at the base, but the lowermost 4 cm of the core was very silty and did not have plant macrofossils in suitable quantity for radiocarbon dating. A sample of *Carex* sp. seeds from a core section at 32-34 cmbs yielded a radiocarbon date of approximately 2200 cal BP (Table 1), indicating that the SLA core represents peat development in the late middle to late Holocene.

WP634. The peat core from WP634 was collected from one of several palsas in a bog on the south side of the Denali Highway (63.1903 N, 147.612464 W, 874 masl). A hammer corer was used to core the upper, thawed portion of the palsa to a depth of 57 cmbs, and a SIPRE auger was used to core the underlying frozen palsa to a depth of 134 cmbs. Coring was halted at the contact of the peat and underlying gravel. Vegetation on the palsa consists of super-abundant shrub birch and moss, common low-bush cranberry, narrow-leaf Labrador tea, blueberry, and crowberry, few willow, and rare shrubby cinquefoil (*Potentilla fruticosa*) and white spruce (seedlings 0.6-1.5 m tall). Vegetation

Table 1. AMS radiocarbon dates from peat cores produced by this study.

Site	Lab no.	Sample depth (cmbs)	Material dated	$\delta^{13}C$ (o/oo)	^{14}C BP	Cal BP (2σ) [1]	Population mean cal BP [1]
Snodgrass A	OS-106752	32-34	12 *Carex* sp. seeds	-24.67	2190 ± 55	2337-2054	2205
Susitna Dune Bog B	OS-107197	107-109	14 *Picea* sp. needle fragments	-27.99	4830 ± 45	5653-5470	5550
	UCIAMS-135110	109-111	Wood	NA	3385 ± 20	3690-3576	3630
WP634	Beta-367975	108-110	*Andromeda polifolia* leaf; 6 *Carex* sp. seeds; *Picea* sp. needle; 2 unidentified leaf fragments	NA	680 ± 30	680-561	629
	OS-107196	132-134	*Ledum palustre decumbens* leaf, 4 *Vaccinium uliginosum* leaves; 7 cf. *Vaccinium uliginosum* leaf fragments	-30.42	>Modern	-	-
WP633	OS-112878	30-31	Wood	-27.47	>Modern	-	-
	Beta-428383	44-47	Wood	-27.20	5220 ± 30	6170-5913	5973
	OS-112877	70-71	cf. *Drepanocladus* sp. moss leaf buds	-33.86	4110 ± 35	4819-4455	4654
	Beta-428382	76-77	Wood	-25.60	4010 ± 30	4566-4417	4479
	OS-112876	114-115	cf. *Drepanocladus* sp. moss leaf buds	-31.06	6760 ± 30	7666-7576	7617
	OS-106220	132-133	32 *Carex* sp. seeds and seed fragments	-25.02	5600 ± 25	6436-6310	6366

[1] Radiocarbon dates calibrated using IntCal 2013 in Oxcal 4.2.

surrounding the palsa consists of superabundant Cyperaceae, and rare shrub birch and willow.

The WP634 core consists of thawed peat 0-57 cmbs, compressed peat 57-84 cmbs, icy organic silt 84-100 cmbs, organic silt with less ice 100-103 cmbs, and peaty organic silt 103-134 cmbs. Plant macrofossils between 110 and 134 cmbs yielded radiocarbon dates of 680-561 cal BP and > modern (Table 1). These dates were surprisingly young, given the depth below surface of the samples, and the fact that the lowest sample dates the contact of peat and underlying gravel presumably representing glacial outwash. Nonetheless, the WP634 core radiocarbon data suggest that this core represents late Holocene peat development in the study area, but because of the dating inconsistencies, more work needs to be done to better assess the record of peat development represented by this core.

WP633. The peat core from WP633 was sampled from one of several palsas on the southern edge of a small lake just south of the Denali Highway (63.187032 N, 147.598854 W, 850 masl) (Figure 6). A hammer core was used to collect a core in unfrozen peat to a depth of 33 cmbs, then a SIPRE auger was used to collect a core in frozen peat to a depth of 134 cmbs. The WP633 core reached sandy sediment, suggesting it neared the base of the palsa, but did not reach gravel because the SIPRE coring device became stuck in frozen peat. Vegetation on the cored palsa is shrubby: shrub birch (*Betula glandulosa*), blueberry (*Vaccinium uliginosum*), and moss (Bryophyte) are superabundant;

Cyperaceae and narrow leaf Labrador tea (*Ledum decumbens*) are abundant; bog rosemary (*Andromeda polifolia*) and crowberry (*Empetrum nigrum*) are common. In-between palsas, *Carex* is superabundant and *Eriophyllum* is abundant. Rare *Picea* sp. dot the hills south of the sampling location.

The thawed peat recovered in the hammer core 0-15 cmbs contained abundant *Sphagnum* sp. moss, and has abundant roots from shrub birch growing on the palsa. Between 15-33 cmbs the hammer core section consisted of compressed peat and organic silt. The frozen section of the palsa collected with the SIPRE auger (33-134 cmbs) contained several ice lenses 1-2 cm thick and consisted of graminoid peat in the upper portion, transitioning to gray silty peat with organics between 90-134 cmbs. Between 44-51 cmbs there was a noticeable color change to a maroon, oxidized color, and the texture of the core became more clay-like. Because the lower portion of the core was so icy, it began to melt and deform, so the SIPRE core was generally sectioned into 2-cm thick sections, although at particularly icy levels the sections were 3 to 5 cm. In particular, the portion of the core between 40-63 and 80-113 cmbs had to be sampled in 3-5 cm core sections because of significant ice lensing. The rest of the core was sampled in 2-cm core sections. As much as possible, this study focused on 2-cm core sections from the WP633 core.


Figure 6. Overview of WP633 peat core sampling location facing south from the Denali Highway.

Plant macrofossils from 133 cmbs yielded a radiocarbon date of approximately 6436-6310 cal BP (Table 1), indicating that the WP633 core represents peat development from the early-mid Holocene through modern times. Because the WP633 core represents the longest time scale of the cores collected for this study, it was selected for sedimentary, pollen, and plant macrofossil analysis. Five additional samples from the WP633 core were radiocarbon dated, yielding radiocarbon dates of 7666-7576 cal BP, 4566-4417 cal BP, 4819-4455 cal BP, 6170-5913 cal BP, and > modern (Table 1).

Radiocarbon results from plant macrofossil analysis yielded stratigraphically inconsistent results; this is likely because two of the samples submitted for radiocarbon dating consisted of aquatic moss (OS-112877 and OS-112876). Previous studies indicate that aquatic moss tends to produce radiocarbon dates that are older than the actual age of the deposit (Birks and Birks 2000). A third stratigraphically inconsistent date on unidentified wood (Beta-428383) may be the result of old wood washing into the sampling location. The results of analyses on the WP633 peat core are presented below.

WP633 Organic Carbon and Magnetic Susceptibility Analysis

Loss-on-ignition analysis was conducted on all core sections between 13 to 134 cmbs (Figure 7). Percent organic content (% OC) shows three peaks: 0-31 cmbs representing modern peat vegetation in the upper portion of the core, 66-67 cmbs, and 109-113 cmbs. There are six significant dips in % OC: there is a gradual decrease around 38-43 cmbs, corresponding with the oxidized, clayey horizon described above, followed by two abrupt drops at 56-59 cmbs and 70-71 cmbs, followed by another gradual drop at 116-117 cmbs corresponding with the silty peat portion of the core, and an abrupt drop at 133-134 cmbs marking the transition between peat and underlying sandier sediments.

Magnetic susceptibility (MS) was conducted on all core sections between 13 to 134 cmbs; the uppermost modern vegetation was excluded from this analysis. An increase in MS typically corresponds with an increase in sedimentation at the coring location, usually through the addition of aeolian sediments or tephra fall (discussed further below). There are as many as nine peaks in the MS data (Figure 7). Significant MS peaks in the WP633 core for the most part all correspond with a decrease in % OC described above, supporting the inference that the time represented by these core sections was characterized by increased sedimentary deposition.

WP633 Vegetation Record

Paleoecological results from WP633 indicate a relatively consistent pollen signature in the study area for the past 6400 calendar years (Figure 7). Cyperaceae (21-42%) and *Betula* (18-36%) pollen typically dominated the pollen assemblage throughout the core, with lesser amounts of *Alnus* (12-29%) and *Picea* (7-20%). *Salix* was also present at a relatively constant proportion (2-9%). Ericales pollen was absent or present in low amounts (1%) in the lower portion of the core, but generally increased towards the upper portion (2-6%, excluding 70-71 cmbs). *Artemisia* pollen was either absent or present in low amounts (1-3%), as was Poaceae (0-1%). *Typha latifolia*, an aquatic species, was represented (1%) in several core sections.

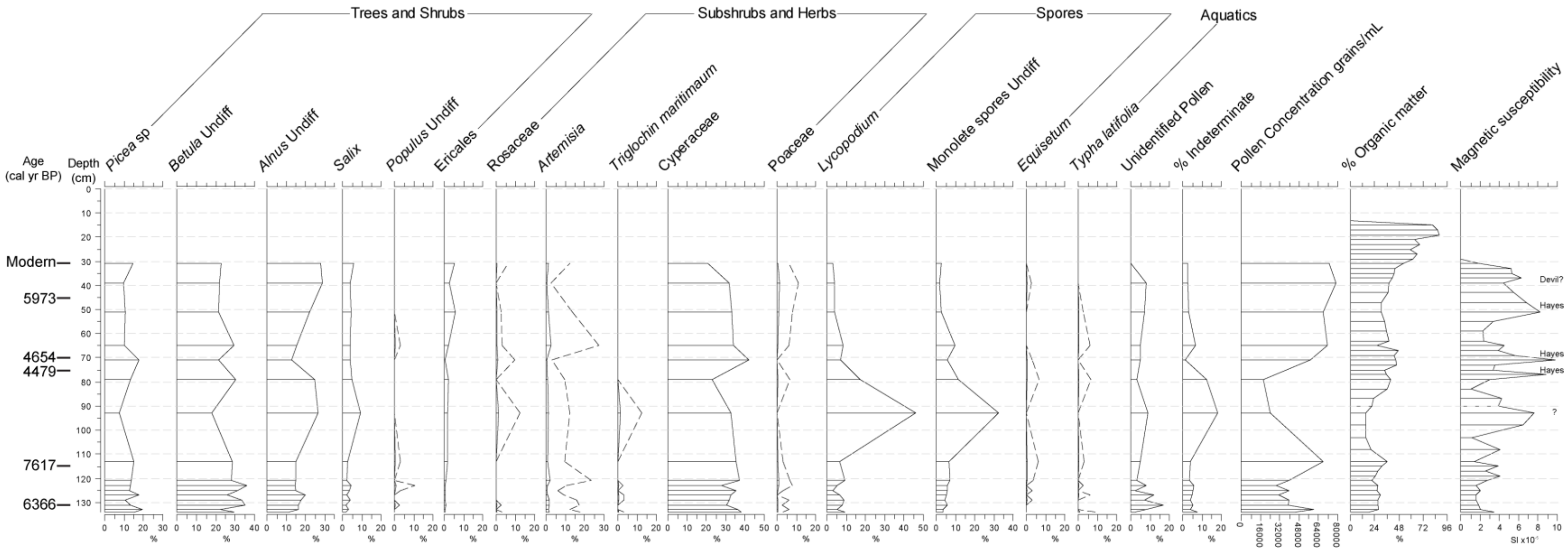

Figure 7. Stratigraphic diagram showing pollen, loss on ignition, and magnetic susceptibility data. Dashed lines represent a 10x exaggeration to increase visibility.

Indigenous *Lycopodium* spp. spores were present in relatively constant amounts (3-9%), with exception of samples between 91-93 cmbs (46%) and 78-79 cmbs (17%). Monolete spores exhibited a similar pattern; they were present in relatively constant amounts (2-10%), except for in the samples between 91-93 cmbs (33%) and 78-79 cmbs (12%). The core segments between 91-93 cmbs and 78-79 cmbs show a significant drop in pollen concentration and an increase in the percentage of degraded pollen grains counted as indeterminate. The core section between 91-93 cmbs is the only sample that does not have a total terrestrial pollen count of at least 300 grains. Counting in this sample stopped at ~170 terrestrial grains because pollen concentration was low, and many pollen grains were too degraded to identify, so the data were considered suspect.

The plant macrofossil record from WP633 (Figure 8) offers additional insights into the vegetation record at the sampling location. The plant macrofossil record supports Cyperaceae as an important taxa at the coring location; *Carex* sp. seeds were the most common plant macrofossil identified throughout the core. *Picea* plant macrofossils are present in the earliest core sections, indicating that spruce trees were likely growing at the sampling location as early as 6400 cal BP. Macrofossils of *Betula glandulosa* and other shrubby taxa were also in the earliest core sections, indicating that shrub birch was also growing at the sampling location by 6400 cal BP.

Aquatic species *Stuckenia filiformi* and wetland species *Meyanthes trifolata* were present in the earliest core sections, but not in later core sections.

Non-*Sphagnum* moss is abundant to superabundant in the lower sections of the core, but decreases in abundance as *Sphagnum* increases. *Sphagnum* moss was absent from the core until it becomes abundant at approximately 50 cmbs. There were relatively very few plant macrofossils identified in core sections 76-77 cmbs and 91-93 cmbs compared to other samples. Chironomid larvae were present in lower portions of the core, and Cladocera show two peaks, one in the lowermost portion of the core, and another around 70 cmbs, prior to dropping out of the record in the uppermost portion of the core. Chironomid larvae live in freshwater habitats (Walker 2007), while Cladocera live in lakes and ponds (Rautio and Nevalainen 2007).

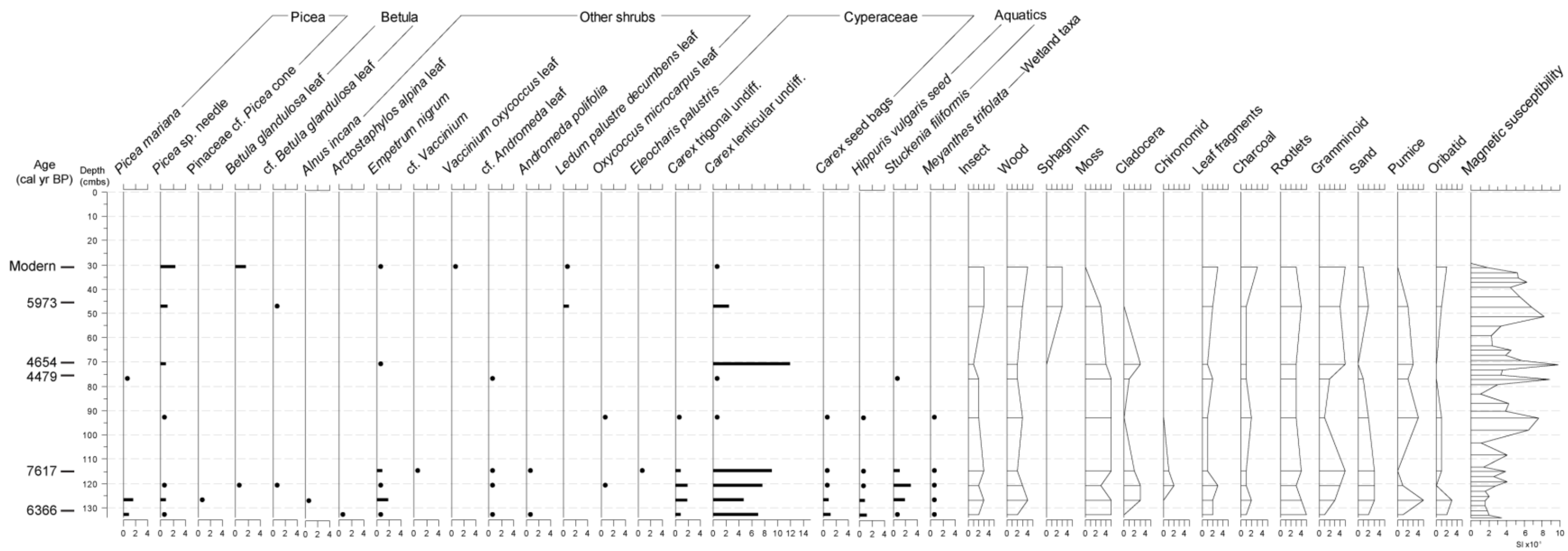

Figure 8. Stratigraphic diagram showing plant macrofossil and ordinal scale data. All macrofossil taxa presented here represent seeds unless otherwise noted. Macrofossil concentration shown as number per 10 ml.

Discussion

Age of Peat Deposits in the Upper Susitna Basin

Undeniably, the radiocarbon record for the upper Susitna peat cores is problematic. There are stratigraphically inconsistent radiocarbon dates on all cores with more than one radiocarbon date. There are date reversals in the WP633 core, the Susitna Dune Bog core, and date reversals and seemingly inaccurate dates (given core depth) in the WP634 core. The reasons for these problematic radiocarbon dates are presently unknown, but may be related to cryoturbation.

Stratigraphically inconsistent dates in the WP633 core may be partly the result of submitting aquatic taxa for radiocarbon dating. Aquatic taxa can show a reservoir or hard-water effect resulting in older than expected radiocarbon dates (Birks 2001). This study submitted two samples of *Drepanocladus* sp. aquatic moss for radiocarbon dating (OS-112876 and OS-112877); both of these samples yielded older than expected radiocarbon ages when compared to dates obtained from terrestrial species (Table 1). In addition, a sample of wood from 44-47 cmbs (Beta-428383) yielded an older than expected radiocarbon age when compared to dates on short-lived seeds and leaves (Table 1); this may be the result of older wood washing into the mire, and this sample is also considered suspect for interpreting core age. A sample of wood from 30-31 cmbs yielded a modern radiocarbon age; this sample was from the transition from thawed peat to frozen peat, and represents a younger than expected date given its stratigraphic position. It could be due to some mixing of thawed material as the core was being extracted from the bog. Date reversals in the region are not uncommon; there are examples from previous research in the Susitna basin (Dilley 1988; Dixon and Smith 1990; Personius et al. 2010). This phenomenon needs to be better explained moving forward to improve paleoecological research in the region, not to mention the reliability of a vegetation history developed from the peat bogs.

There are three dates that appear to be the most secure for the WP633 core. The sample from 132-133 cmbs (6436-6310 cal BP) (OS-106220) is probably a reliable age for the base of the core, because this date was derived from *Carex* sp. seeds representing species growing within one meter of the sampling location. Radiocarbon dates from 76-77 cmbs (unidentified wood; 4566-4417 cal BP) (BETA-428382) and 70-71 cmbs (*Drepanocladus* sp.; 4819-4455 cal BP) (OS-112877) are also considered to be fairly reliable dates; although the 70-71 cmbs date is on *Drepanocladus* sp. (aquatic moss) and is probably older than the actual age of the core section, these two dates overlap at two sigma suggesting a broadly reliable age range for the portion of the core between 70-77 cmbs.

The basal radiocarbon dates from Snodgrass A (2337-2054 cal BP), Susitna Dune Bog B (5653-3537 cal BP), WP634 (680-561 cal BP), and WP633 (6436-6310 cal BP) suggest that all of the peat deposits cored for this study represent Holocene peat formation, and mostly middle to late Holocene peat formation. Previous research, however, suggested that early Holocene peat formation occurred in the region, too. The Snodgrass Lake peat core with a basal peat date of ~2200 cal BP (presented here) was collected from the same general location as a peaty organic-silt bulk sample collected from the contact of a palsa and underlying ice disintegration deposits that previously yielded a date of ~10,400 cal BP (Reger and Bundtzen 1990). A similar date of ~10,200 cal BP was obtained on a bulk sample from the base of a peat deposit overlying fluvial sand in the Boulder Creek drainage north of the Clearwater Mountains (Figure 5) (Reger and Bundtzen 1990). It may be that the bulk samples collected for the Reger and Bundtzen (1990) study included aquatic taxa, and yielded older dates because of a reservoir effect.

Based on the radiocarbon dates obtained for this study, it appears that in the upper Susitna basin peatlands may have formed significantly later than the early Holocene, which is unexpected given previous research suggesting that most peatlands in Alaska formed during the early Holocene (Jones and Yu 2010). The radiocarbon issues with the WP63 core make any discussion of the timing of events represented in the core somewhat tenuous, but moving forward this dissertation will rely on the three dates presented here as acceptable to establish the age of paleoecological events represented by the core.

Loss on Ignition and Magnetic Susceptibility

Magnetic susceptibility (MS) data show as many as nine peaks in MS that are likely related to periods of aeolian sediment and/or tephra deposition at the sampling location. There are four significant MS peaks that post-date ~4500 cal BP and may represent iron-rich tephra deposits. These could be related to the Hayes tephra set H (Watana) and Devil tephra documented in other settings in the study area. The uppermost MS peak at 36-37 cmbs could represent the Devil tephra, roughly dating to ~900 to 600 cal BP, given the proximity of this peak to the modern radiocarbon date at 30-31 cmbs.

There are three MS peaks underlying this, a cluster of peaks between 40-54 cmbs, and two distinct peaks at 70-71cmbs and 76-77 cmbs. The two lowermost peaks were directly dated to see if they represented deposits of Hayes tephra set-H (OS-112877 and Beta-428382). At ~4400 to 4600 cal BP, these two MS peaks are slightly older than the earliest dates for Hayes set H tephra deposits (Riehle 1985; Wallace et al. 2014), but at two sigma they are within 100 to 200 years of these earliest Hayes tephra set H dates. This suggests that these two peaks could represent Hayes set H deposits. No discrete tephra horizons were observed in the 70-71 cmbs and 76-77 cmbs core sections; nevertheless, the MS peaks offer evidence for tephra fall.

An MS peak from samples between 40-51 cmbs corresponds with the maroon oxidized, clayey horizon described above, and could represent a tephra fall. Previous research indicates that tephra layers in peat can act as a barrier to translocating weathered materials (De Vleeschouwer et al. 2008); this section of the core could represent a zone of accumulated oxidized materials. The oxidized color is very similar to that of the Hayes tephra set H at terrestrial settings in the study area. It is possible that this represents the uppermost Hayes set H deposit, and the most substantial tephra deposited in the study area.

Supporting this interpretation, Rohr (2001) identified three tephra layers in a lacustrine core from Swampbuggy Lake, a thick tephra dating to approximately 4000 cal BP that she identified as the Jarvis Ash (i.e., Hayes tephra set H), and several thin tephra horizons underlying the Jarvis Ash that she did not identify. The lower, thin tephra horizons were associated with a radiocarbon date of 4300 cal BP, similar to the age of the two small MS peaks described here. Given recent research supporting several tephra deposition episodes resulting in the Hayes set H tephra identified in terrestrial deposits (Wallace et al. 2014), it is likely that Rohr's multiple horizons all represent Hayes set H deposits, as do the three MS peaks described here. The chronological information gleaned from the MS data supports the hypothesis that the radiocarbon dates from 70-71 cmbs and 76-77 cmbs represent accurate dates.

The WP633 core does not appear to be old enough to have captured the Oshetna tephra documented in the upper Susitna study area and throughout southcentral Alaska at 6870-6660 cal BP (Child et al. 1998). The earliest date on the core is just 300 years after this event, so the pollen and plant macrofossil data in the lowest portion of the core could represent a landscape still affected by tephra deposition.

Ordinal tephra pumice abundance scores roughly match with the MS peaks (Figure 8), but there is pumice in most samples, suggesting post-depositional movement of pumice throughout the peat profile. Previous research indicates that tephra can move as much as 15 cm upward (possibly the result of movement with plant growth and rising water table) and downward (through gravity) in peat formations, but should still maintain a peak presence in the original tephra depositional horizon (Payne and Blackford 2008).

Core sections with low percent organic carbon (OC) generally correspond with peaks in magnetic susceptibility, supporting the inference that the MS peaks represent aeolian sediment and/or tephra deposition (Figure 7). In general, the lowermost portion of the core exhibits lower percent OC than the upper portion of the core. Fens typically have a lower percent OC than peat bogs (Mitsch et al. 2009), so taken with other evidence (discussed below), this suggests that the sampling location may have been a fen-like setting for most of the time period represented by the core, but changed to a peat bog in more recent time, represented by the higher percent OC in the upper portion of the core.

Pollen and Plant Macrofossils

Vegetation in the study area consisted of shrub-birch tundra for the entire time period represented by the core. The taxa represented in the pollen record are typical shrub-tundra species. The presence of *Betula glandulosa* plant macrofossils suggests that the *Betula* pollen dominating the pollen record is likely shrub-birch pollen, not tree birch. Pollen from wind-distributed species like *Alnus* and *Picea* can travel long distances from their source, especially in treeless environments like the shrub and alpine tundra that typifies the majority of the study area today (Birks and Birks 2000). However, *Alnus* and *Picea* pollen are present in amounts greater than 10%, typically the threshold used to suggest taxa growing locally (Hu et al. 1993). There are *Picea* and *Alnus* macrofossils in the core, indicating that these taxa were growing at the coring location in the past. Nonetheless, the relatively minor percentages of the pollen record represented by *Picea* and *Alnus* suggest that these taxa were only minor components of the vegetation in the study area for the entire time period represented by the core, as expected in shrub-birch tundra near contemporary treeline.

Modern vegetation surrounding the WP633 sampling location consists of shrub-birch tundra, with sparse spruce trees dotting the low hills around the sampling location. The presence of *Picea* plant macrofossils throughout the core indicates that *Picea* was present on this landscape from 6400 cal BP to the present. The presence of *Picea* sp. macrofossils, especially the Pinaceae cf.

Picea cone fragment recovered near the base of the core, suggests that *Picea* may have been located directly on the sampling location in the past. This may be related to cooler, wetter conditions and increased *Picea* density, and may be supported by fluctuations in *Picea* pollen in the lowermost sections of the core. However, *Picea* needles are found in the uppermost section of the core sampled for plant macrofossils (with a modern radiocarbon date), and there are no *Picea* growing directly on the sampling location today (though they are not far away), so there may be some downhill movement of *Picea* needles, possibly from erosion, wind transport, surface water, or snow melt (Glaser 1981). This may explain the older than expected wood date near the top of the core as well.

Pollen and plant macrofossil data suggest that the sampling site was a pond or fen from 6400 cal BP until the late Holocene or modern times. Fens are open peatland systems that typically receive drainage from surrounding mineral soils, and are often covered by graminoid species and brown mosses. Poor fens typically receive water from groundwater and precipitation, and are considered transitional peatlands, representing the transition between a rich fen and peat bog. Fens contrast with bogs, which receive most or all of their moisture from precipitation, and support acid-loving vegetation, in particular mosses (Mitsch et al. 2009).

Non-*Sphagnum* moss (including one type provisionally identified as *Drepanocladus* sp.) and graminoid fragments dominate most of the core, until *Sphagnum* moss appears towards its very uppermost portion. *Drepanocladus* mosses typically prefer wet, shallower fen-like settings (Johnson et al. 1995), and a diverse community of plants, including bryophytes, sedges, and grasses typically dominate fens (Mitsch et al. 2009). *Eleocharis palustris*, *Stuckenia filiformis*, and *Hippuris vulgaris* prefer shallow-water habitats (Hultén 1968). *Meyanthes trifolata* prefer bogs and ponds (Hultén 1968). The presence of macrofossils from these taxa indicates they were growing at the sampling location from 6400 cal BP through the mid-Holocene, suggesting the sampling location was a shallow pond or fen-like setting during this time.

Cyperaceae pollen and *Carex* spp. plant macrofossils are the dominant taxa represented throughout the core, except for the very uppermost sections. Cyperaceae typically grow in mesotrophic-poor fens, although some taxa can also be found in ombrotrophic bog-pool communities (Mauquoy and Van Geel 2007). While only represented in small amounts, the presence of *T. latofolia* pollen suggests a pond or fen-like setting, given that the species is typically found in water shallower than 50 cm (Finkelstein 2003). Chironomid and Cloderocera peaks in the lower portion of the core support a pond or fen-like environment.

The presence of *Empetrum nigrum* throughout most of the core suggests that there were well-drained hummocks present at the sampling location. *E. nigrum* is intolerant of prolonged waterlogging, and typically grows on well-drained hummocks in peat bogs, or at the margin of peat bogs (Mauquoy and Van Geel 2007). The consistent presence of wood fragments throughout the core, along with plant macrofossils from shrubby taxa, suggests shrubs were growing at the sampling location during the earliest time represented by the core. These data suggest more of a fen-like setting, and not an open pond.

Shifts in the proportions of Cyperaceae pollen and *Carex* seeds could represent shifts in available moisture over time. Specifically the decrease in Cyperaceae pollen at ~80 cmbs just prior to 4479 cal BP could represent dryer conditions, possibly related to warmer conditions in the middle Holocene, and the subsequent increase in Cyperaceae pollen at ~70 cmbs (~4654 cal BP) could represent wetter conditions during Neoglacial cooling (Blackford et al. 1992). This is tenuous though, and needs to be supported with additional data.

It is more likely that shifts in the proportion of Cyperaceae pollen and *Carex* seeds represent mire response to tephra deposition. Hughes et al. (2013) suggest that tephra deposits can shift the balance of mire communities in favor of monocotyledons such as *Carex* species, possibly as a result of a fertilization effect caused by enhanced mineralization of peat and/or liberation of plant nutrients from the surface coatings of tephras, and from leaching of the volcanic glass. Lotter and Birks (1993) found that grass and sedge pollen increased following tephra deposition at two study sites in Germany, possibly attributed to vegetation changing in response to tephra fall. The increase in Cyperaceae pollen at ~70 cmbs occurs at the same time as a tephra deposit possibly attributed to the Hayes set H tephra fall. However, Blackford et al. (2014) found evidence that Cyperaceae communities were negatively affected by tephra deposition, and that Poaceae thrived more in the resulting nutrient-rich setting, so correlating a spike in Cyperaceae pollen to tephra fall may be an oversimplification of a complex process of ecosystem response to tephra fall. Determining whether the WP633 coring location was a fen or bog becomes important when considered in light of these studies linking changes in ecosystem nutrient regimes and associated peatland type to episodes of tephra deposition.

There is additional evidence for potential vegetation response to tephra fall in the WP633 peat core. Samples from core sections 76-77 cmbs and 91-93 cmbs have low plant macrofossil concentrations, while samples from core sections 78-79 cmbs and 91-93 cmbs have low pollen concentrations, an increase in the amount of indeterminate pollen grains, and an increase in *Lycopodium* and monolete spores. Low pollen concentration values could mean less vegetation on the landscape, or it could be related to post-depositional degradation of pollen grains.

In particular, pollen from core sample 91-93 cmbs are very degraded. This sample is the only sample that did not have a total terrestrial count of at least 300 grains. Many of the *Lycopodium* spores in this sample were only identifiable as *Lycopodium* sp. because they were so degraded, whereas in other samples *Lycopodium* spores were identifiable to the species level. Many pollen grains counted as *Betula* and *Alnus* in this sample were also very degraded and difficult to identify. These same core samples correspond with a decrease in percent OC, a magnetic susceptibility spike, and abundant tephra pumice, together suggesting that these core sections represent periods of tephra deposition. The 76-79-cmbs core sections could relate to Hayes tephra set H, but the origin of the tephra represented in the 91-93 cmbs core section is unknown.

Previous research on vegetation response to an eruption of the Aniakchak Volcano 3600 cal BP reported that pollen concentration values dropped significantly following the eruption, possibly representing unstable substrates and discontinuous vegetation (Vanderhoek and Nelson 2007). Plant taxa that prefer disturbed habitats (e.g., *Artemisia* and other Asteraceae) increased. Pollen grains in samples following tephra deposition were abraded and degraded, suggesting contact with sharp mineral matter in aeolian transport. This research suggested a period of 2000 years for vegetation and landscape recovery nearby the volcano, where it was covered by pyroclastic flow, a significantly more destructive event than a distal tephra fall (Vanderhoek and Nelson 2007). Alternatively, the dramatic increase in spores and decrease in identifiable pollen could be related to a post-depositional taphonomic process that degraded the more sensitive pollen, but not the more robust spores.

Several studies have presented palynological evidence for vegetation response to tephra fall (e.g., Blackford et al. 1992; Charman et al. 1995), but there are criticisms of this evidence, and the more recent consensus appears to be that palynological studies have not been able to convincingly prove vegetation response to tephra deposition (Payne et al. 2013). Studies incorporating several lines of evidence in addition to the pollen record have shown variable response in mire systems following tephra deposition, likely the result of a complex set of interacting factors (Hotes et al. 2004; Hughes et al. 2013; Payne and Blackford 2008).

The decrease in Cyperaceae pollen and *Carex* seeds and shift to *Sphagnum*-dominated peat towards the top of the core may represent a natural process like pond infilling, or vegetation succession from fen to peat bog. The general developmental trend of sub-arctic wetlands is typically an evolution from a dry depression to open water, open fen, shrub fen, and finally to treed fens and bogs (Zoltai et al. 1988). Peat bogs often represent a late stage of post-glacial lake basin infilling (Mitsch et al. 2009). Alternatively, the decrease in Cyperaceae pollen and *Carex* seeds towards the top of the core could represent a mire recovering from tephra deposition and shifting to a nutrient-poor oligotrophic bog (Hughes et al. 2013). This transition correlates with an MS peak that could represent deposition of a tephra that is part of Hayes tephra set H (as described above). If this is an accurate correlation then the shift from fen to bog may have occurred within the past 3600 calendar years.

Overall, the vegetation of the study site does not seem to have changed dramatically over time. The same shrub-tundra species that are present today were generally present in the past. There is evidence for a shift from fen-like conditions to sphagnum-palsa peat bog at the specific coring location, possibly following deposition of the last of the Hayes set H tephras in the study area 3600 cal BP, and a possible shift in *Picea* density over time, from denser spruce nearby the coring location 6400 cal BP, to sparser spruce cover more distant from the coring location in subsequent years. There are preliminary indications that tephra deposition may have promoted Cyperaceae communities, and that there are lower pollen concentration values associated with tephra falls, but additional research is needed to better support these preliminary findings.

The Upper Susitna in the Context of Central Alaska Range Paleoecology

The paleoecological data presented here suggest that *Picea* was established at its modern position in the upper Susitna basin by 6400 cal BP, complementing Rohr (2001) and Bigelow and Edwards (2001) findings that the spruce forest had stabilized at modern treeline by 7400 cal BP The upper Susitna data, however, calls into question the Long Tangle Lake record suggesting that spruce was not well established until 3800 cal BP (Ager and Sims 1981). This does not mean that treeline did not fluctuate throughout the Holocene; just that *Picea* was on the landscape in proportions similar to that of today by the early-mid Holocene.

The pollen data from this study suggest that vegetation in the study area has remained relatively stable; this is similar to the pattern at Windmill Lake, where the pollen record suggests that vegetation remained relatively stable throughout the MH and LH (Bigelow and Edwards 2001). Despite the apparent stability in vegetation during the MH and LH, the paleoecological record for the upper Susitna basin tentatively supports Rohrs' (2001) findings that there may be subtle shifts in vegetation patterns during the Holocene, indicating that with continued high-resolution paleoecological research, we may be able to fine-tune our understanding of upland vegetation response to climate change and ecosystem disturbance.

Methodological Considerations

As stated at the outset of this chapter, this study collected cores from peat deposits because they offered a chance to study the localized vegetation history of the upper Susitna basin, and because pollen and plant macrofossils are typically well preserved in peat. This study tested several methods for extracting peat cores from peat bogs, using a Russian peat corer, a hammer corer, and a SIPRE auger. The Russian peat corer proved ineffective for cutting into wet peat with abundant roots, and the design of the coring device was such that it did not sample the bottom 10 cm. Because of typically shallow ice, the corer could only collect 10-20 cm of thawed peat. Because of these drawbacks, the Russian peat corer was quickly abandoned.

The hammer corer and SIPRE auger each had an upside and a downside. The hammer corer was effective at capturing peat from the upper, thawed portion of the profile, but the resulting core was typically compressed, potentially affecting post-extraction sampling intervals and age-depth modeling. The SIPRE auger worked well for frozen peat deposits provided they were not too deep and we did not risk getting the auger stuck and frozen in the ground. However, when the SIPRE auger was used on thawed peat deposits, it simply chewed up the peat and did not produce a usable core.

Extracting peat cores specifically from palsas had significant methodological drawbacks, too. As described above, the peat cores extracted from the upper Susitna had significant ice lensing in them, and this was apparently a bigger issue in the upper Susitna than in previous studies that were the present study's inspiration (e.g., Eisner et al. 2003; Eisner et al. 2005). Ice lenses in the peat cores melted quickly in the summer heat, leading to rapid deformation of thawing core sections once extracted, causing irregular sampling intervals in some cases. In addition, ice lenses represent post-depositional deformation/inflation of peat stratigraphy, making commonly used paleoecological methods such as age-depth modeling and peat accumulation rate calculations problematic.

Finally, there were significant issues with stratigraphic reversals in radiocarbon dates from the upper Susitna basin peat cores. These may be related to stratigraphic deformation that occurs as a result of palsa ice lens formation, seasonal freeze-thaw cycles, or solifluction. Additionally, as described above, Blackford and Payne (2008) found evidence for tephra pumice moving up and down in peat deposits. If tephra pumice can readily move through peat, then it is possible that the plant macrofossils (small seeds, spruce needles, etc.) dated in this study could have moved through the peat profile as well. In summary, this study was not as effective at answering the research questions laid out at the outset because of the methodological issues detailed here. Moving forward, serious consideration needs to be given to these issues prior to additional paleoecological research using peat cores, at least in the upper Susitna basin.

Conclusions and Future Research

Paleoenvironmental reconstructions based on a single core are always tentative. There are limitations to what the pollen and macrobotanical data form one core can tell us about paleovegetation, paleoclimate change, and ecological response to tephra fall. Despite these limitations, however, this paper provides important baseline ecological data for an understudied area, the uplands of the central Alaska Range, and provides some initial assessments of vegetation change in response to climate change and tephra fall.

One of the primary goals for this research project was to develop a high-resolution local record of paleoecological change for the study area, using both pollen and plant macrofossil data. In particular, this study revisited a peat bog section previously dated to the Pleistocene/Holocene transition, to capture the paleoecological record for this important time of transition. Unfortunately, our efforts to capture the LP/EH record were unsuccessful, and we succeeded only in obtaining a record of paleoecological change for the past 6400 calendar years. The paleoecological record from WP633 indicates that by this time, modern vegetation patterns had already been established, so we were unable to answer the question of whether the pollen record from upland Windmill Lake represented the sequence of vegetation change in the upper Susitna basin. Despite this setback, this dissertation offers the following conclusions:

1. Bog and fen-like mire deposits are difficult to date. Aquatic taxa can provide unusually older radiocarbon ages due to reservoir effect, and in northern environments older material, for example tree macrofossils, can easily wash into a fen. Date reversals in the upper Susitna basin from this study and previous studies need to be explained prior to additional efforts to extract paleovegetation data from peat deposits in the region.
2. Based on the radiocarbon data presented in this study, mires in the upper Susitna basin appear to have formed in the middle to late Holocene. A more detailed study of peat deposits across the study area may shed light on why the upper Susitna basin appears to have later peat development than most of Alaska.
3. There are four significant peaks in magnetic susceptibility after 6400 cal BP, and these appear to represent four episodes of mid- to late-Holocene tephra deposition. These episodes are likely related to the mid-Holocene Hayes set H and late-Holocene Devil tephra deposit based on radiocarbon ages, but this needs to be confirmed with teohrochronological data.

4. The WP633 sampling location was likely a fen-like setting for most of the time period represented by the core, but changed to a peat bog more recently, possibly shortly after deposition of the final Hayes set H tephra in the upper Susitna basin. There is evidence for increased spruce density at the coring location in the early-middle Holocene, and decreased spruce density in the middle and late Holocene.
5. Vegetation in the study area consisted of shrub-birch tundra for the entire time represented by the core. The presence of *Picea* plant macrofossils throughout the core indicates that *Picea* was present from 6400 cal BP to the present.
6. Despite issues assigning tephra deposits to particular eruptions, the paleoecological record can still be used to assess whether tephra deposits significantly affected mire composition. Shifts in the proportion of Cyperaceae pollen and *Carex* seeds may represent vegetation change in response to a change in nutrient regimes following tephra deposition. Lower pollen concentration values associated with possible tephra deposits may represent changes in vegetation cover in response to tephra fall.

CHAPTER III

REGIONAL STRATIGRAPHY, TEPHROCHRONOLOGY, AND HUMAN OCCUPATION OF THE UPPER SUSITNA BASIN

The mountainous uplands of the upper Susitna basin, central Alaska Range (Figure 9) played an important role in seasonal subsistence rounds for western Ahtna Athabaskan hunter-gatherers. Historic and ethnographic accounts describe a seasonal subsistence round centered on upland caribou hunting in the summer and early fall, and lowland fishing in lake- and stream-side winter villages (Irving 1957; Kari and Fall 2003; Kari 2008; Reckord 1983). There is debate about when in prehistory this strong seasonal pattern of landscape use emerged; some research suggests that upland landscapes played a relatively minor role in subsistence settlement systems until the middle Holocene (MH), as land-use strategies adapted to changing climatic and ecological conditions (e.g., expanding boreal forest) (Potter 2008a, 2008b, 2008c), while others suggest that the uplands played an important role in subsistence activities in the late Pleistocene (LP) and early Holocene (EH), for example during climate shifts in the Younger Dryas and EH as hunters spread through the uplands pursuing mobile herd animals (Graf and Bigelow 2011; Mason et al. 2001) and other seasonally available subsistence resources (Wygal 2009, 2010), or as part of a broad-based, wide-spectrum LP/EH subsistence strategy (Yesner 2001).

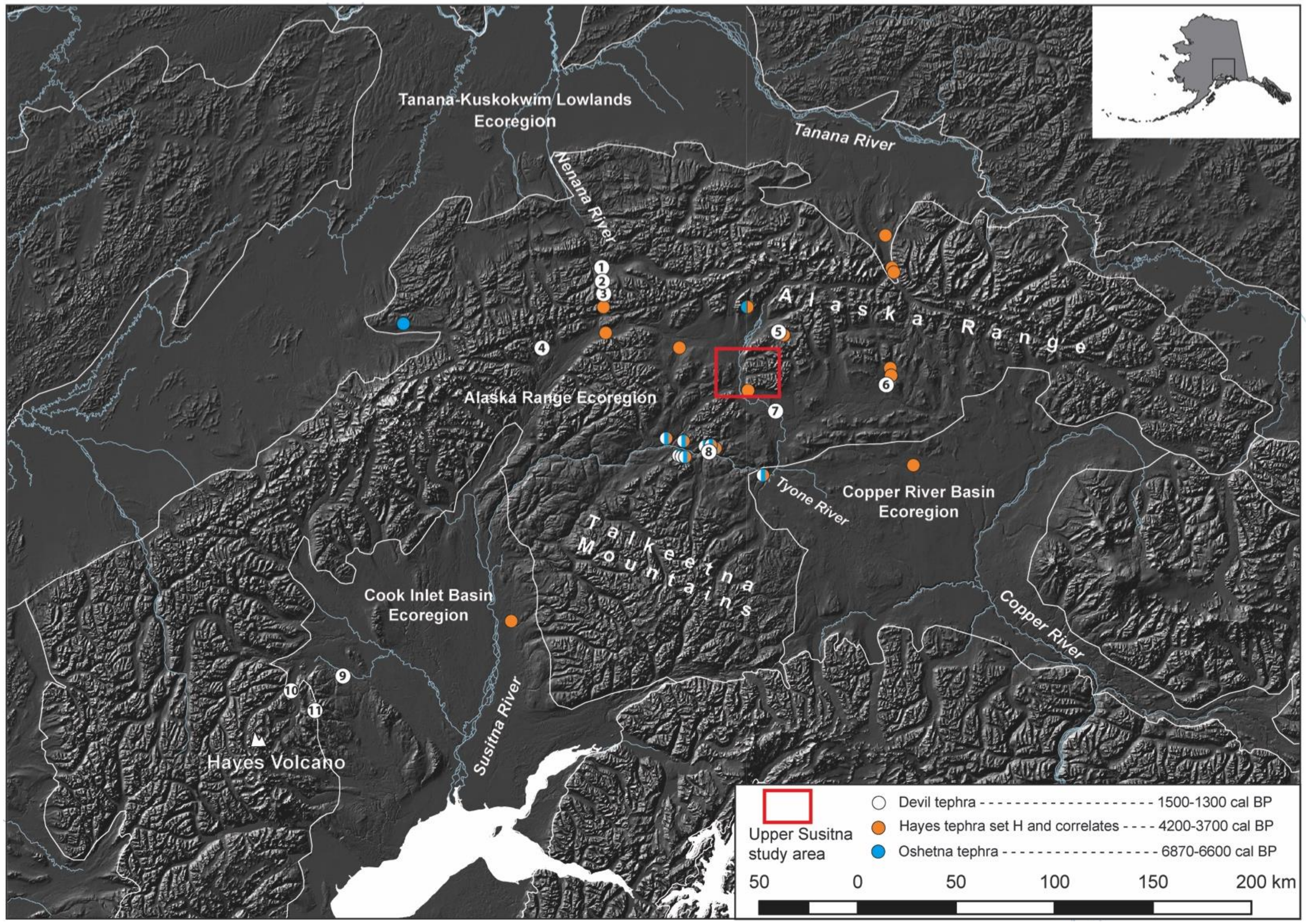

Figure 9. Map of Central Alaska Range showing the Alaska Range Ecoregion and other nearby ecoregions, as well as important paleoecological and archaeological sites mentioned in text: 1, Windmill Lake; 2, Eroadaway; 3, Carlo Creek; 4, Bull River II; 5, Boulder Creek (Reger and Bundtzen 1990); 6, Phipps, Whitmore Ridge, Sparks Point; 7, Rubin and Alexander (1960) sampling location; 8, Jay Creek Ridge; 9, Site 27; 10, Hayes River Outcrop; 11, Hayes River Pass. Colored circles represent distal tephra sampling locations used for comparative analysis in this study.

Holocene volcanism may also have affected human use of marginal upland ecosystems; previous research in Alaska indicates that Holocene tephra falls (for example the White River ash and tephras derived from the Veniaminof and Aniakchak volcanoes) prompted significant ecological changes and corresponding demographic shifts in hunter-gatherer populations (Mullen 2012; Vanderhoek 2009; Vanderhoek and Nelson 2007).

This study presents geomorphic, stratigraphic, tephrochronological, and chronological data from the upland upper Susitna River basin, central Alaska Range. The goal of this research is to create a model of landscape change and record of human use for the upper Susitna study area, to assess when and how prehistoric humans used this landscape, and how human adaptive strategies in the study area changed in response to LP and Holocene climate change, and in response to ecosystem disturbance by tephra fall. This research asks the questions: What is the landscape history of the upper Susitna basin? When did humans first occupy the upper Susitna basin, and what was the environmental/geomorphic context of initial occupation? What is the sequence of archaeological site occupation through the Holocene? And how did landscape change and Holocene tephra fall affect human use of the uplands?

This study finds that the upper Susitna study area was deglaciated by 14,000-13,000 cal BP but was not settled for more than 2000 years after this. There is evidence for ephemeral occupation of the study area in the EH, and a marked increase in intensity of occupation during the MH and late Holocene

(LH), with a possible hiatus in the late MH, and evidence for shifting strategies of landscape use within the uplands from the MH to LH. There are three, and possibly four, tephra falls represented in the study area, but so far there is no clear evidence that tephra fall significantly affected human occupation in the upper Susitna basin. Instead, a late MH occupation hiatus may more likely be related to climate instability during the Neoglacial Period.

Glacial History

There are four phases of late Wisconsin glaciation recognized in the Alaska Range: peak glaciation during the Last Glacial Maximum (LGM) ~22,000 cal BP, gradual retreat to an ice margin ~19,000-17,000 cal BP, a series of standstills and short advances 17,000-16,000 cal BP, rapid and significant retreat of glacial ice after 16,000 cal BP, then a brief but strong re-advance 14,000-12,000 cal BP Glaciers again retreated after 12,000 cal BP, marking the end of full glacial conditions. At some locations in Alaska, there is evidence for a minor re-advance 12,000-11,000 cal BP, correlated with cooling during the Younger Dryas, but limited to the upper reaches of mountain valleys (Briner and Kaufman 2008; Hamilton 1994; Kaufman et al. 2011; Ten Brink and Waythomas 1985; Thorson 1986, Wahrhaftig 1958).

During the LGM in the Susitna study area, the Nenana, West Fork, and Susitna glaciers flowed south from the Alaska Range to coalesce with glaciers flowing from the Talkeetna Mountains to form an ice sheet extending west across Monahan Flat and the Nenana River basin, and south through the Susitna basin. During this time glacial ice blanketed most of the study area except for the uppermost elevations (Briner and Kaufman 2008; Dortch et al. 2010; Hamilton and Thorson 1983; Reger et al. 1990; Reger and Bundtzen 1990; Smith 1981; Thorson et al. 1981; Woodward-Clyde 1982).

LGM glacial ice extended through the upper Susitna basin at least as far as the Hatchet Lake moraine (Figure 10), and possibly as far south as the confluence of the Susitna and Tyone rivers (Hamilton and Thorson 1983; Reger and Bundtzen 1990; Smith 1981; Thorson et al. 1981; Williams 1989; Woodward-Clyde 1982). The eastern side of the Hatchet Lake moraine is blanketed with lacustrine deposits (Reger and Bundtzen 1990; Smith 1981; Williams and Galloway 1986), likely representing the western edge of Glacial Lake Ahtna, a large proglacial lake covering the Copper Basin during the late Wisconsin (Bennet et al. 2002; Ferrians 1963, 1989; Nichols 1956, 1965; Reger et al. 2011; Weidmer et al. 2010; Williams 1989). Lacustrine deposits on the ~800 masl Hatchet Lake moraine could have been deposited by Lake Ahtna at its estimated 18,000 cal BP high stand of 800 masl, before draining around 14,000 cal BP (Ferrians 1989; Reger et al. 2011; Williams 1989).

Following the LGM, there appear to have been two pulses of glacial advance and retreat in the study area, possibly correlating with the 19,000-17,000 cal BP and 17,000-16,000 cal BP phases represented in the regional record. Moraine features high in the upper Butte Creek valley suggest that during these two pulses, glacial ice covered most of the study area (Woodward-Clyde 1982); however, it is possible that ice partially retreated during the period of significant glacial ice recession recognized regionally after 16,000 cal BP.

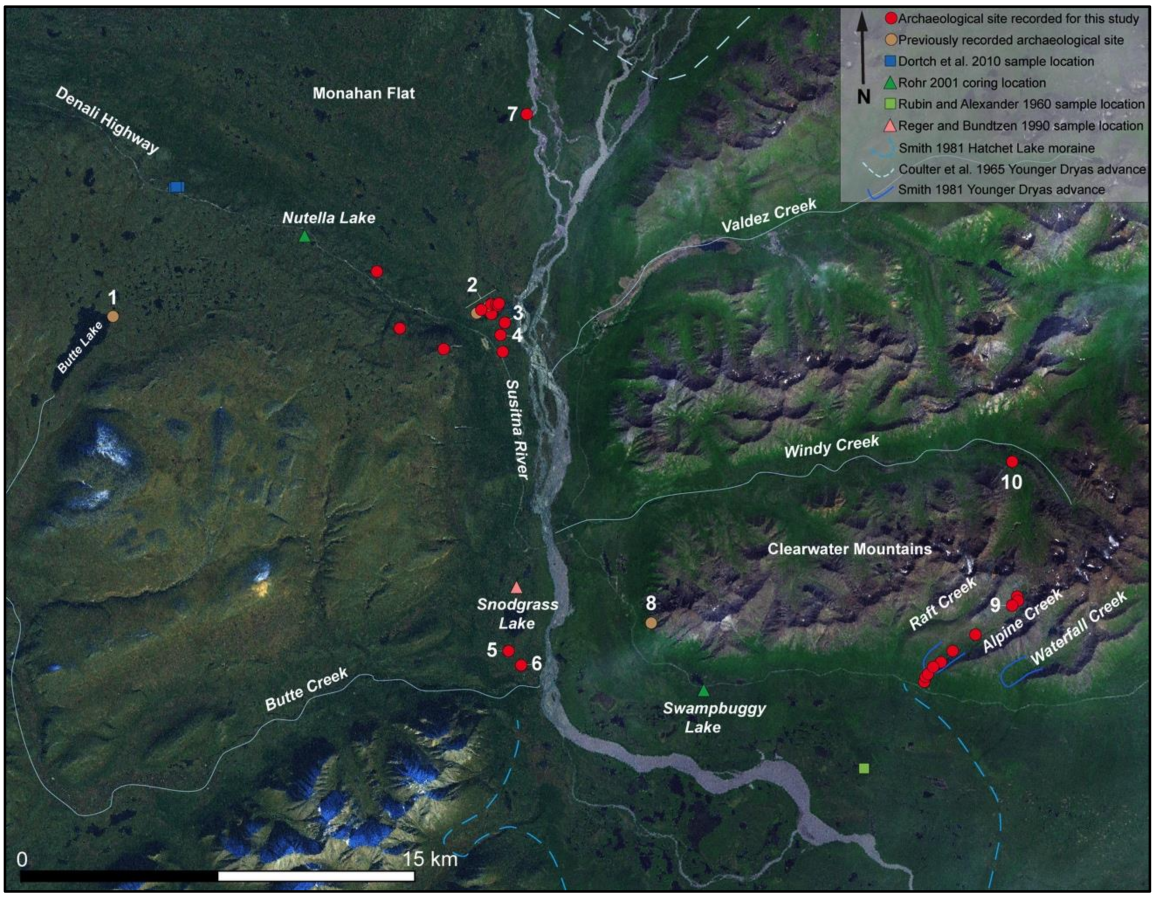

Figure 10. Upper Susitna study area and sites mentioned in text. 1, Butte Lake (HEA-189); 2, Susitna Dune sites (see Figure 11); 3, Susitna River 2 (HEA-502); 4, Susitna River 3 (HEA-455); 5, Snodgrass Lake 1 (HEA-500); 6, Butte Creek 1 (HEA-499); 7, West Fork Susitna (HEA-506); 8, Ratekin (HEA-187); 9, Alpine Creek 8 (HEA-460); 10, Windy Creek 1 (HEA-505).

The final significant phase of glaciation in the study area extended across Monahan Flat, but did not extend into the upper Butte Creek valley. Glacial ice flowed down the Susitna valley to the confluence of Butte Creek and the Susitna River, and extended ~20 km up the Butte Creek drainage from the mouth of the Butte Creek valley (Smith et al. 1988; Woodward-Clyde 1982). This final phase of significant glaciation began to recede east across Monahan Flat towards the present-day Nenana and West Fork glaciers 14,000-13,000 cal BP (Dortch et al. 2010). This correlates with the regional Alaska Range and Copper Basin records, which indicate that full glacial conditions terminated by 14,000-13,000 cal BP (Hamilton 1994; Kaufman and Manley 2004). Following termination of full glacial conditions, glacial ice receded rapidly from the study area, leaving hummocky ice disintegration deposits in topographically low areas (Woodward-Clyde 1982).

Following termination of full glacial conditions, a less extensive glacial re-advance was primarily confined to the upper mountain valleys, filling some valleys in the Clearwater Mountains, including Alpine Creek and Raft Creek, to the edge of the Susitna River valley bottom south of the Clearwater Mountains (Figure 10) (Reger et al. 1990; Reger and Bundzten 1990; Smith 1981; Woodward-Clyde 1982). In the southern Alaska Range, the West Fork Susitna and Susitna glaciers re-advanced, possibly as far south as the confluence of the West Fork Susitna and Susitna Rivers (Figure 10) (Coulter et al. 1965). These re-advances have previously been attributed to Holocene glaciation, but more recent research indicates that glaciers throughout Alaska receded to modern positions, or possibly even a more retracted position, by the beginning of the Holocene (Barclay et al. 2009; Briner and Kaufman 2008; Hamilton 1994), suggesting that the re-advances described correlate with the Younger Dryas re-advance recognized regionally 12,000-11,000 cal BP. Recent research at the headwaters of the Susitna River indicates that silt and peat deposits nearby the West Fork and Susitna glaciers date to 8000-7000 cal BP (Personius et al. 2010), ruling out a significant MH or LH re-advance. This supports other researchers' assertions that the upper Susitna basin was not significantly affected by later Holocene glacial re-advance (Dixon et al. 1985; Reger et al. 1990; Woodward-Clyde 1982).

Tephrochronology

Research in the middle Susitna basin in the Talkeetna Mountains (Figure 9) established a tephrochronological framework of Holocene tephra fall, used to correlate archaeological components throughout the basin. This framework was based on a sequence of tephra horizons informally named the Devil, Watana, and Oshetna tephras (Table 2), distinguished in the field using color, texture, and relative stratigraphic positioning, and typically separated by aeolian sedimentary units and/or paleosols (Dilley 1988; Dixon et al. 1985:I, II; Dixon and Smith 1990; Romick and Thorson 1983).

Table 2. Tephra horizons as described in the middle Susitna basin.

Tephra name	Age estimate	Color	Field texture	Thickness	Petrography cp/op/am[1]	Glass geochemistry	Other observations
Devil[2]	1420-1516 ^{14}C BP[3]	Pale brown (10YR 6/3) to pinkish white (7.5 YR 8/2)[2]	Silt loam[4]	Typically 3-5 cm, but up to 8 cm[2, 4]	Dominated by pumaceous glass and glass-mantled plagioclase and hornblende, rare biotite, 0/4/96[4, 5]	Rhyolitic glass[4]	Well preserved, unweathered, below organic mat, easily identifiable in field[4]
Upper Watana (oxidized)[2]	1850 – 2700 ^{14}C BP[3]	Dark brown (7.5 YR 4/6) to reddish brown (2.5 YR 3/4)[2]	Loam to sandy loam[4]	Typically 5-10 cm, but as thin as 2 cm[2, 4]	Dominated by pumaceous glass and glass-mantled plagioclase and hornblende, rare biotite, 0/4/96[4, 5]	Rhyolitic glass[4]	Oxidization ranges from pale brown stain to cemented layer, but primarily consists of small granular concretions[2]
Lower Watana (unoxidized)[2]	1850 – 2700 ^{14}C BP[3]	Brownish-yellow (10YR 6/6)[2]	Loam[4]	5-10 cm, as thin as 1 cm[2, 4]	Dominated by pumaceous glass and glass-mantled plagioclase and hornblende, rare biotite, 0/3/97[4, 5]	Rhyolitic glass[4]	Gradational contact based on color and texture; infrequently a thin paleosol, sometimes with cultural material, marks upper boundary[2, 3, 4]
Oshetna[2]	5130 ± 120 – 5900 ± 135 ^{14}C B.P.[3]	Light brownish gray (2.5Y 6.2)[2]	Silt loam to sandy loam[2, 4]	3-5 cm[2, 4]	Variable, higher % plagioclase and quartz, distinct population of hornblende, glass poor, rare biotite. 0/3/68[4, 5, 6]	Rhyolitic and dacitic glass populations[4]	Burned organic horizon marks boundary; typically mixed with underlying sand units; rests on glacial drift[4]

[1] Clinopyroxene/orthopyroxene/amphibole ratio
[2] Dixon et al. 1985:1
[3] Dixon and Smith 1990
[4] Dilley 1988
[5] Romick and Thorson 1983
[6] Dixon et al. 1985:II

Initial tephra characterizations in the middle Susitna valley included field descriptions and laboratory granulometric, petrographic, and glass geochemical analyses (Dilley 1988, Dixon et al. 1985:II; Dixon and Smith 1990). Table 2 provides a summary of middle Susitna tephra characteristics. Electron probe microanalysis (EPMA) of glass geochemistry indicates that the Devil, upper Watana, and lower Watana tephras are very similar and cannot be distinguished from one other geochemically. The Oshetna tephra, however, contains two populations of glass shards, a rhyolitic glass population similar to rhyolitic glass in the Devil and Watana tephras, and a distinct dacitic glass population (Romick 1984 in Dilley 1988).

A lacustrine core extracted from the middle Susitna valley contained six tephra horizons, suggesting that the tephra history of the region could be more complex than represented at terrestrial locations (Dixon and Smith 1990); however, there were issues correlating the lacustrine and terrestrial tephra horizons, possibly related to contaminated radiocarbon dates (Dilley 1988; Dixon and Smith 1990). This highlights the prevailing issues with the tephra record of the middle Susitna, which in turn hinders our ability to securely use these tephra horizons as a tephrochronological marker to interpret archaeological site chronology.

The overall similar mineralogy of the Devil, upper Watana, lower Watana, and Oshetna tephras led to the hypothesis that all four originated from the same source vent. Romick and Thorson (1983) correlate the four middle Susitna tephras with the Hayes Volcano, located in the northern Tordrillo Mountains (Figure 9), based on the presence of biotite and hornblende minerals (known to occur regionally only at the Hayes vent), and broadly concurrent radiocarbon dates with proximal Hayes-derived tephra deposits. However, mineralogical, geochemical, and chronological differences in the Oshetna tephra could also indicate a different source vent, and some investigators have been hesitant to correlate the Oshetna tephra with the Hayes Volcano (Dilley 1988; Dixon et al. 1985:II).

From approximately 4200-3700 cal BP the Hayes Volcano produced a series of closely-spaced tephra ejections known informally as Hayes tephra set H (HH), with an estimated composite volume of 10 km^3, representing the most significant Holocene eruptive sequence in the Cook Inlet region (Riehle 1985, 1994, 2000; Riehle et al. 1990; Wallace et al. 2014; Waythomas and Miller 2002). There are two stratigraphic sections documenting proximal HH deposits nearby the Hayes Volcano: Hayes River Pass (Site 23) (Riehle 1985, 1994; Riehle et al. 1990), and Hayes River outcrop (KLW001) (Wallace et al. 2014) (Figure 9). At Hayes River Pass (HRP), HH consists of seven sequential tephra horizons, 23-G (oldest) through 23-A (youngest), estimated to have been deposited over a period of decades to possibly a century or two (Riehle 1985; Riehle et al. 1990). Petrographic and EPMA glass geochemical analyses of tephra samples from HRP show that tephra deposits here are similar to each other in that they have high amphibole/pyroxene ratios, biotite in trace amounts, similar SiO_2 contents, calc-alkaline glass, and dacitic whole-rock compositions (Riehle 1985).

At Hayes River outcrop (HRO), there are seven tephras, B (oldest) through H (youngest) with a lower limiting age of 4000-4100 cal BP that generally correlates with the HH deposits described at Riehle's HRP (Wallace et al. 2014). Similar to HRP, HH tephras at HRO have dacitic whole-rock composition, high proportions of amphibole to pyroxene, biotite in trace amounts, and rhyolitic glass geochemistry. Major-element glass geochemistry and mafic mineral proportions do not conclusively distinguish among HH deposits at HRO; however, preliminary results suggest that individual layers can be distinguished using Fe-Ti oxide grain composition analysis (Wallace et al. 2014). The Cook Inlet region is the likely geographic source for tephras in the Susitna basin based on prevailing wind patterns (Waythomas and Miller 2002). These analyses indicate that the Hayes Volcano has produced distinct, high-silica rhyolitic eruptive products in comparison to other Cook Inlet volcanoes (e.g., Spurr, Redoubt, Iliamna, Crater Peak, and Augustine) (Wallace 2003; Wallace et al. 2014).

Methods

Archaeological Fieldwork

Archaeological fieldwork consisted of investigating a variety of landforms in different settings throughout the upper Susitna study area, to locate and radiocarbon date archaeological sites. Fieldwork consisted of two parts: archaeological survey and test excavation. Survey consisted of non-random surface survey and shovel testing of elevated landforms, focusing on high-probability locations (e.g., Hoffecker 1988) and erosional exposures. Test units were excavated on landforms with low surface visibility and at archaeological sites identified during surface survey. Test excavations consisted of 50-cm^2 or 1-m^2 test units, excavated with trowels by natural strata, using 5-cm arbitrary levels if strata reached >5 cm in thickness. Charcoal, lithic tools, significant lithic debitage, and significant bone fragments encountered during test excavation were three-point provenienced, and all sediment was screened through 1/8” mesh to recover additional remains.

For each test unit with cultural material, sediments and stratigraphy were documented following Birkeland (1999). Optically stimulated luminescence (OSL) samples were collected by driving a small section of copper tube into a profile wall and collecting sediment surrounding the sample to determine background radiation. Bulk sediment samples were collected from stratigraphic profiles for most test units. These data were used to interpret cultural context and site-formation processes.

Dating

To establish the chronology of upland landscape use, charcoal samples associated with archaeological materials were collected for AMS ^{14}C dating, and tephra samples were collected from archaeological excavation units to establish a tephrochronology. This study looks to overcome bias in radiocarbon dating of certain time periods by using tephrochronology to date sites, thereby assigning an age range to all archaeological material. The National Ocean Sciences Accelerator Mass Spectrometry Facility at the Woods Hole Oceanographic Institution analyzed charcoal samples using standard AMS radiocarbon dating techniques.

Radiocarbon dates were calibrated using OxCal V4.2 with IntCal13 calibration (Bronk Ramsey 2009; Reimer et al. 2013) to better understand the timing of geomorphic processes that shaped the upper Susitna basin. OSL samples were collected from the base of a sand dune located in the study area, and they were analyzed following procedures defined by the Luminescence Dating Research Laboratory at University of Illinois, Chicago (UIC-LDRL). UIC-LDRL analyzed the OSL sample presented here utilizing a single aliquot protocol (Murray and Wintle 2000).

Loss-On-Ignition

Loss-on-ignition (LOI) sediment analysis methods followed standard procedures (Holliday 2004; Stein 1984; Wang et al. 2011). Sediment samples were air dried, then screened through 2-mm screen to remove intrusive roots and large gravel. A 5.00-g subsample was weighed into a ceramic crucible using a digital scale. Samples were heated at 100°C for one hour in a drying oven, cooled in a desiccator for 30 minutes, and then re-weighed to the 0.01 g; this is the dry sample weight. Samples were then placed in a cool muffle furnace, heated to 500°C, burned for two hours at 500°C, cooled in the furnace to ~150°C, placed in a dessicator for 30 minutes to cool, then weighed to the 0.01 g; this is the non-organic carbon sample weight. The percent organic carbon in the samples was calculated following Stein (1984) (see formula in chapter II).

Tephra Characterization

Field description of upper Susitna tephra deposits followed stratigraphic description methods in Birkeland (1999). Tephra deposits in the study area were correlated in the field using physical properties (e.g., color, bed thickness, pumice color, mineralogy) and stratigraphic relationships between tephra horizons. Laboratory analyses of tephra samples consisted of physical descriptions of tephra pumices and electron probe microanalysis (EPMA) of glass geochemistry (e.g., Alloway et al. 2007; Lowe 2011; Wallace et al. 2014). One teaspoon of sediment was subsampled from bulk tephra samples collected in the field, and the remaining sample was archived for future research. Tephra subsamples were wet-sieved through a set of graded screens (0.250 mm, 0.125 mm, 0.062 mm) and then air-dried. Each size fraction was assessed under 10-20x magnification using a dissecting microscope; tephra grain size and component class were described following White and Houghton (2006), and dry pumice color was scored using a Munsell Rock Color Book.

For EPMA analysis, tephra pumices were handpicked from the 0.250-mm fraction using a dissecting microscope, mounted in epoxy, polished, and coated with graphite. Single-shard EPMA glass analysis was conducted on tephra pumice glass to determine the proportion of major element oxides present in tephra glass. Single-shard glass analyses provide the benefit of revealing individual glass populations, or identifying mixed/reworked deposits (Froggatt 1992). Samples AT-2790 and AT-2791 were analyzed by Kristi Wallace at the USGS Tephrochronology Laboratory in Menlo Park, California (USGSMP); samples HEA-455-S2, HEA-455-S3, and HEA-455-S4 were analyzed by the author at the Texas A&M University Department of Geology and Geophysics Electron Microprobe Laboratory (TAMUEML).

At USGSMP, glass analyses were conducted using wavelength dispersive techniques with a 5-spectrometer JEOL 8900R electron probe microanalyzer. Concentrations were determined with the CIT-ZAF reduction scheme (Armstrong 1995). Glass analyses used a 5-µm-diameter beam with 5 nA current and 15 kV accelerating potential. Reported glass compositions are the averages of 10–25 spot analyses or fewer if multiple populations were found within a single sample; background intensities were determined 1-3 times for each grain. Count times were 10 seconds for Na, which was analyzed first to reduce Na-loss, 10 seconds for S and Cl, and 30 seconds for remaining elements. During analysis, sets of 5–10 replicate analyses of USNM glass standard RLS-132 and various mineral standards (Jarosewich et al. 1979) were performed to monitor instrument drift. Natural glass and mineral standards were used for calibration: RLS-132 for Si; basaltic glass VG2 for Fe, Mg, and Ca; Orthoclase 1 for K and Al; Tiburon albite for Na; Mn_2O_3 for Mn; TiO_2 for Ti; Sodalite for Cl; and Wilberforce apatite for P (K. Wallace, personal communication, 2014).

At TAMUEML glass analyses were conducted on a four-spectrometer Cameca SX50 equipped with a PGT energy dispersive system. Concentrations were determined using the Pouchot and Pichoir (PAP) reduction scheme (Pouchot and Pichoir 1985). Glass analyses used a 5-µm-diameter beam with 5 nA current and 15 kV accelerating potential for Na, Si, Al, Mg, Cl, K, Ca, and Fe. Following this, a second round of glass analyses was performed using a 5-µm-diameter beam with 50 nA current and 15 kV accelerating potential for P, Ti, and Mn, to obtain trace element readings above the detection limit (Guillemette 2008). Glass compositions are the averages of approximately 15-25 individual spot analyses or fewer if multiple populations were found within a single sample. Background intensities were measured at each analytical point. Prior to analysis, USNM glass standard 72854 (VG-568) (Jarosewich et al. 1980) was analyzed to ensure proper instrument calibration. Count times were 10 seconds for Na (analyzed first to reduce Na-loss) and Cl; 30 seconds for Si, Al, Mg, K, Ca; 40 seconds for Fe; 45 seconds for Ti and Mn; and 90 seconds for P. Natural glass and mineral standards were used for calibration: rhyolitic glass VG-568 for Si; basaltic glass VG-2 for Fe, Mg, and Ca; Charles M. Taylor (CMT) Orthoclase for K and Al; CMT Amelia albite for Na; CMT spessartine for Mn; CMT TiO_2 for Ti; CMT NaCl for Cl; and CMT apatite for P. Published values for all natural glass and mineral standards used in both USGSMP and TAMUEML analyses are generally within one standard deviation of our analyzed values.

Following analysis, glass point data were normalized to 100% to compensate for variable glass hydration and to facilitate comparison between samples (Froggatt 1992). Typically 20-25 points were selected for analysis, providing a margin of error that allowed bad data points to be discarded (Kuehn et al. 2011; Lowe 2011). Glass point data were rejected if they fit the following criteria: obvious non-tephra analyses (mineral grains), analyses with < 90 wt % raw total (low total/bad analyses), analyses with > 20 wt % Al2O3 (feldspar), analyses with elemental concentration below EPMA detection limits, and single outliers in otherwise similar grain populations (cf. Addison et al. 2010; Wallace 2003). The standard deviation (SD) was calculated for each sample to assess the amount of variation in point data for each major element oxide. If a sample exhibited a high SD, then EPMA glass data was graphically plotted in element-

element plots in an attempt to identify populations or outliers that were causing a high standard deviation (Froggat 1992). Mean geochemistry was calculated for each glass population; the mean composition data presented here for each population reflects the average composition of the melt phase that produced the tephra (Shane 2000). Glass populations were classified using the Total Alkali-Silica (TAS) classification system. A TAS diagram graphs the relationship between the combined alkali content and silica content; this relationship is a proxy measure for mineral composition used to classify volcanic rock (Le Bas et al. 1986).

Tephra Correlation

Tephra deposits identified in the upper Susitna basin were correlated to regional tephra deposits based on a suite of characteristics, including physical (bedding color, pumice color), stratigraphic, chronological, and geochemical characteristics (Lowe 2011; Sarna-Wojcicki 2000). The goal of this analysis was to establish correlations between upper Susitna study area tephras and regional proximal and distal tephra horizons, to attribute the tephras to a source volcano and regional volcanic events, and provide tephrochronological data to interpret archaeological assemblages.

This research stems from previous tephrochronological research in the middle Susitna basin, but reassesses the geochemical similarity of distal tephra deposits in the Susitna basin with more recent, higher-precision data published since the middle Susitna analysis of the 1980’s. Upper Susitna samples were compared to proximal geochemistry data from Hayes River Pass and Hayes River Outcrop (Riehle 1994; Wallace et al. 2014); distal glass composition data from the Devil, Watana, and Oshetna tephras in the middle Susitna basin (Dilley 1988); Site 27A, a late Holocene Hayes-related tephra that has been suggested to be correlated to the Devil tephra (Dilley 1988; Riehle 1985; Wallace et al. 2014); regionally widespread Hayes set H-correlated tephras including the Jarvis Ash Bed (aka Jarvis Creek ash), Cantwell ash, and Tangle Lakes tephra (Begét et al. 1991; Personius et al. 2010); and Oshetna-correlated tephras from Wonder Lake (Child et al. 1998) and the headwaters of the Susitna River (Personius et al. 2010) (Appendix A).

To compare tephra geochemical data from the study area to previously published data, this study used the similarity coefficient technique (SC), a measure of multivariate similarity (following Borchardt et al. 1972). The SC is advantageous because it is a simple, rapid means of comparing tephra deposits, it is a more rigorous than graphical data comparison, and it reduces large EMPA data sets to a single quantitative number expressing the degree of correlation between two tephra samples (Froggatt 1992; Hunt and Hill 1993; Riehle 2000). The SC has been commonly used in Alaska to correlate tephra horizons (e.g., Beget et al. 1991; Riehle 1985, 1994, 2000). The present study did not use the weighting option presented in Borchardt et al. (1972); instead, following Riehle (1985), oxides that typically had a normalized weight percent (wt %) of < 0.40

were excluded from the SC calculation. While < 0.40 wt % is somewhat of an arbitrary cutoff, it strengthens the SC calculation by removing low concentration oxides that may be below the minimum EPMA detection limit (Riehle 1985, 2000).

Previously published data varies in the number of element oxides reported. To compare the upper Susitna EPMA data to previously published EPMA data, it was necessary to remove oxides to make data sets comparable. This SC analysis compared oxides of Si, Al, Fe, Mg, Ca, Na, and K, and eliminated Cl and oxides of Mn and P because they were inconsistently reported, and Ti oxide because the majority of analyses reported were < 0.40 wt %. These criteria eliminated upper Susitna data that is below EPMA minimum detection limits and therefore statistically insignificant.

This study follows previously published similarity coefficient correlations applied to tephrochronological research in Alaska. An SC of ≥ 0.95 represents the same tephra fall or same tephra set with high degree of similarity, an SC of 0.93-0.94 represents a tephra set or same tephra fall with unreliable element concentrations, and a SC of 0.90-0.93 represents the same tephra set, but not the same fall, provided stratigraphy and mineralogy is consistent (Riehle 1985). Distal tephras correlate to proximal tephra deposits if they have an SC of ≥ 0.94 (Beget et al. 1991; Riehle et al. 1990). A sample will have an SC of 1 with itself, indicating identical wt % for all elements, but it is not expected to have an SC of 1 with other samples from the same tephra deposit due to variability in analytical conditions and natural geochemical variability (Riehle et al. 1990). The term “set” is used to describe closely succeeding tephra deposits that have similar glass geochemistry, but based on stratigraphic position cannot represent the same deposit (Riehle 2000).

Results

Site Descriptions

From the period of 2010-2012 we documented 28 previously unrecorded archaeological sites in the Susitna study area. We conducted test excavations at 14 of these sites, and recovered cultural material from primary subsurface contexts at 12 of these. In addition, we conducted test excavations at two previously recorded sites (Figure 10). During test excavations we observed three tephra horizons at most testing locations, and we found evidence for a possible fourth tephra at some locations. The three most ubiquitous tephras were provisionally correlated in the field to the Devil, Watana, and Oshetna tephras described in the middle Susitna basin based on color, weathering characteristics, texture, and relative stratigraphic positioning, while the fourth tephra has not been correlated to any known tephra. Here I present descriptions of archaeological sites recorded and tested during our fieldwork, followed by a more detailed look at the tephras identified in the field by comparing physical and geochemical characteristics with previously studied tephras in the region.

Susitna Dune 1 (HEA-454)

Susitna Dune 1 is located at 790 masl on a large, linear, southwest-to-northeast trending sand dune, overlooking Monahan Flat to the north, and the Susitna River to the east (Figures 10 and 11). Vegetation at the site is shrub tundra. Shrub birch (*Betula glandulosa*) is abundant; crowberry (*Empetrum nigrum*), lowbush cranberry (*Vaccinium vitis-idaea*), blueberry (*Vaccinium uliginosum*), and dwarf Labrador tea (*Ledum decumbens*) are common; black spruce (*Picea mariana*) and white spruce (*Picea glauca*) are rare on top of the dune, but common on the steep southern slope of the dune.

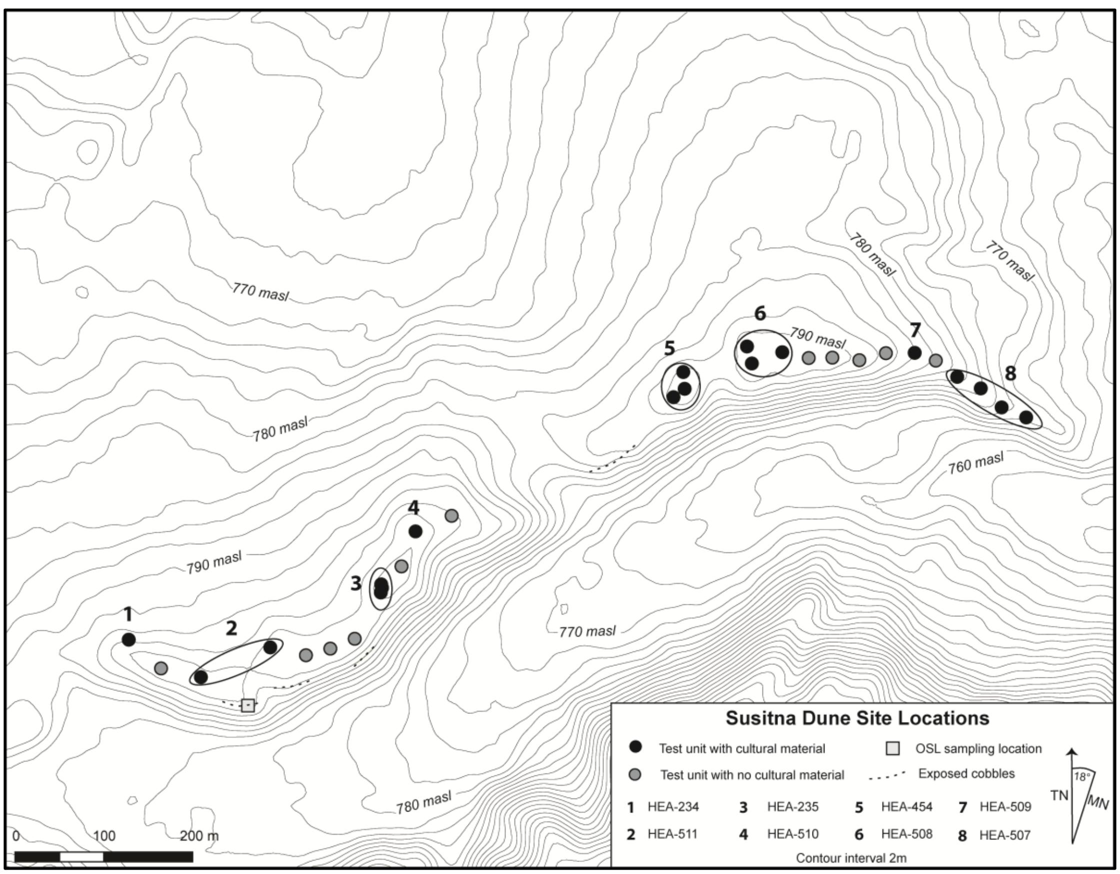

Figure 11. Overview of Susitna Dune.

We excavated four 1-m^2 test excavations at the site (two of these are adjacent to each other totaling a 1 m x 2 m unit), and identified three cultural components. A typical profile at the site consists of a modern O-A-EA-B-BC horizon sequence developed on tephra and aeolian silt sediments, underlain by a series of buried soil profiles developed on tephra and dune sand sediments (Figure 12, Table 3). LOI analysis of sediment samples from test unit N509 E499 show a peak in percent organic carbon (OC) in the A horizon, followed by a significant decrease in the EA horizon, an increase in the B horizon, and decreasing OC in dune sand sediments, with the exception of a slight OC increase in the A/Eb2 horizon. Dune sands at the site are deep; test unit depths reached 220 cm below ground surface before we encountered frozen sand and halted excavation.

Component 3 (C3), the uppermost cultural component at the site, consists of 209 lithics and approximately 316 fragmented faunal remains recovered from a silt loam A horizon and its contact with an underlying EA horizon formed on the Devil tephra. In some test units the EA horizon was ephemerally expressed, and cultural material was recovered from the contact of the A horizon and underlying B horizon presumed to have formed on the Watana tephra; this material is considered part of C3. The C3 context at the site also contained a small depression containing charcoal that may be a hearth feature. Component 2 (C2) consists of 10 lithics in an A/Eb2 horizon approximately 30 cm below C1, distinguished by an increase in percent OC and a charcoal horizon representing surface vegetation burn. Charcoal collected from the charcoal mat yielded an AMS date of 6870 ± 30 ^{14}C BP (Table 4).

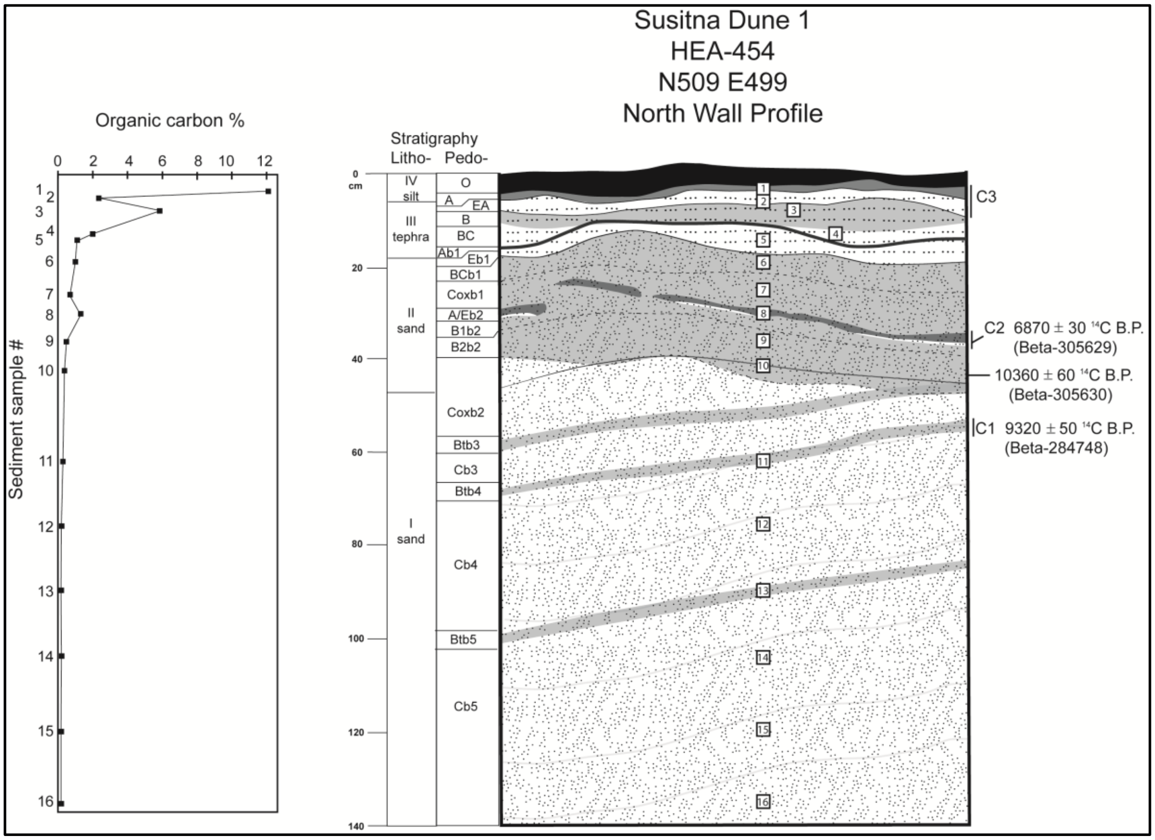

Figure 12. Susitna Dune 1 (HEA-454) profile.

Sediment sample 8 from the C2 A/Eb2 horizon was analyzed at 20-40x under a dissecting microscope and consists primarily of sand, but has estimated tephra pumice content of 10-20%, suggesting it is a reworked tephra deposit (Gatti et al. 2012). This contrasts with sediment samples 6, 7, and 9, which have a very minor amount of small pumice fragments (~1%), with weathered exteriors suggesting they were translocated from overlying tephra horizons. The C2

Table 3. Mineral soil descriptions for Susitna Dune 1 N509 E499 north wall profile.

PU[1]	Description	LU[2]
A	Dark grayish brown (10YR 4/2); silty loam; weak fine granular structure; clear wavy boundary	IV
EA	Light gray (7.5YR 7/1), with common gray (7.5 YR 6/1) and few pinkish-white (7.5 YR 8/2) mottling; sandy loam; weak fine platy structure; small charcoal fragments; abrupt wavy boundary (Devil tephra)	III
B	Dark reddish brown (2.5 YR 2.5/4); sandy loam; weak fine subangular blocky structure; few faint coatings on roots; weakly cemented into pebble size-concretions; clear wavy boundary (Watana tephra)	III
BC	Very pale orange (10YR 8/2) with few light brown (5 YR 6/3) mottles; sandy loam; structureless; abrupt wavy boundary (Watana tephra)	III
Ab1	Dark grayish brown (10YR 4/1); sandy loam; weak fine granular structure; charcoal mat resembling vegetation burn; abrupt smooth boundary	III
Eb1	Light gray (7.5YR 7/1); sandy loam with platy and sub-round clasts <1mm; weak fine granular structure; abrupt wavy boundary (Oshetna tephra)	III
BCb1	Reddish yellow (7.5 YR 6/6); loamy sand with subround to subangular siliceous clasts <1mm; structureless; few faint coatings on roots; gradual wavy boundary	II
Coxb1	Yellowish brown (10 YR 5/6) with few reddish brown (5YR 5/4) mottles; sandy loam with subround to subangular siliceous clasts <1mm; abrupt smooth boundary	II
A/Eb2	Very dark gray (10YR 3/1) A horizon underlain in places with gray (10YR 6/1) E horizon; loamy sand; weak fine platy structure; few fine coatings on rootlets and clasts; abrupt smooth boundary (tephra in sediments, but mostly sand – Oshetna?) This horizon had some reddish-brown staining from downward eluviation of materials, but not significant enough to consider it a welded soil	II
B1b2	Light yellowish brown (10YR 6/4) with common medium reddish-yellow (7.5 YR 6/6) mottles; sandy loam with round to subround siliceous clasts 1-2mm; med subangular blocky structure; few faint coatings on rootlets; reddish-yellow mottled portions of this horizon are weakly cemented into pebble-sized concretions; abrupt wavy boundary	II
B2b2	Light yellowish brown (10YR 6/4) with common reddish brown (5YR 5/4) mottles; sandy loam with platy and subround to subangular clasts 1-10 mm; structureless; few faint coatings on rootlets; reddish brown mottled portions of this horizon and weakly cemented into pebble-sized concretions as large as 25 mm; gradual wavy boundary	II
Coxb2	Light yellowish brown (10YR 6/4) with few reddish brown (5YR 5/4) mottles; bedded coarse to fine sand with round, subround and platy clasts <4 mm; individual sand beds are 10 cm thick and fine upward from coarse to fine sand; structureless; abrupt smooth boundary	I
Btb3	Reddish brown (5YR 5/4) clay ribbons with brown (10YR 4/3) mottling; clay bands typically consist of several (2-5) thin (2-3 mm) bands of clay, and are typically separated by thin (2-4 mm) bands of sand with less clay content; loamy sand; weak fine platy structure; few faint coatings on rootlets; sparse charcoal; abrupt smooth boundary	I
Cb3	Brown (10YR 5/3), bedded coarse to fine sand with round, subround and platy clasts <10 mm; individual sand beds are 10 cm thick and fine upward from coarse to fine sand; structureless; abrupt smooth boundary	I
Btb4	Reddish brown (5YR 5/4) clay ribbons with brown (10YR 4/3) mottling; clay bands typically consist of several (2-5) thin (2-3 mm) bands of clay, and are typically separated by thin (2-4 mm) bands of sand with less clay content; loamy sand; weak fine platy structure; few faint coatings on rootlets; sparse charcoal; abrupt smooth boundary	I
Cb4	Brown (10YR 5/3), bedded coarse to fine sand with round, subround and platy clasts <10 mm; individual sand beds are 10 cm thick and fine upward from coarse to fine sand; structureless; abrupt smooth boundary	I
Btb5	Reddish brown (5YR 5/4) clay ribbons with brown (10YR 4/3) mottling; clay bands typically consist of several (2-5) thin (2-3 mm) bands of clay, and are typically separated by thin (2-4 mm) bands of sand with less clay content; loamy sand; weak fine platy structure; few faint coatings on rootlets; sparse charcoal; abrupt smooth boundary	I
Cb5	Brown (10YR 5/3), bedded coarse to fine sand with round, subround and platy clasts <10 mm; individual sand beds are 10 cm thick and fine upward from coarse to fine sand; structureless; boundary unknown, excavation stopped at frozen sand 220 cmbs	I

[1]Pedistratigraphic unit
[2]Lithistratigraphic unit

Table 4. Radiocarbon dates from the upper Susitna River basin study area.

Site	Laboratory #	Material (wood ID)[1]	Com-ponent	Context	$\delta^{13}C$ (‰)	^{14}C B.P.	Cal B.P. (2σ)[2, 3]	Population mean cal B.P.[2, 3]
Susitna Dune 1 (HEA-454)	Beta-305629	Charcoal	2	Charcoal mat representing surface vegetation burn in A/Eb2 sand and tephra horizon	-24.9	6870 ± 30	7788-7627	7702
	Beta-284748	Charcoal	1	Dispersed charcoal in Btb4 sand horizon	-25.9	9620 ± 50	11,170-10,770	10,970
	Beta-305630	Charcoal	n/a[4]	Dispersed charcoal in B2b2 sand	n/a	10,360 ± 60	12,510-11,990	12,220
Susitna River 3 (HEA-455)	Beta-284747	Charcoal	3	Feature 1, shallow basin-shaped charcoal feature	-23.9	2370 ± 40	2682-2329	2427
	OS-101611	Charcoal (*Picea* sp.)	2	Feature 2, dense hearth associated w/notched points, bone	-26.29	3740 ± 30	4224-3984	4089
	OS-101612	Charcoal (*Picea* sp.)	2	Dispersed charcoal from paleosol at contact of Oshetna and Watana tephras	-26.02	4890 ± 35	5711-5585	5626
	OS-101613	Charcoal (*Salix* sp.)	1	Dispersed charcoal from Ab2 paleosol capping bedrock soils	-26.71	9320 ± 60	10,690-10,300	10,520
Butte Creek 1 (HEA-499)	OS-101614	Charcoal (*Salix* sp.)	1	Feature 1, charcoal hearth feature	-27.43	4060 ± 30	4789-4432	4552
	OS-101615	Charcoal (*Betula* sp.)	1	Feature 2, dense calcine bone hearth feature	-26.58	4280 ± 25	4867-4830	4848
West Fork Susitna 1 (HEA-506)	OS-101395	Charcoal (*Salix* sp.)	1	Dispersed charcoal from AEb1 horizon formed on the Oshetna tephra	-27.12	4510 ± 25	5299-5050	5167

A/Eb2 horizon has field characteristics generally consistent with the Oshetna tephra described in the middle Susitna basin, but the associated radiocarbon date indicates it was deposited prior to the Oshetna tephra and could represent an as yet unidentified fourth tephra horizon in the upper Susitna basin.

Our excavations recovered a single flake from a mottled B2b2 sand horizon approximately 10 cm below the C2 horizon. Dispersed charcoal from this context yielded an AMS date of 10,360 ± 60 ^{14}C BP (Table 4). This unit unconformably overlies bedded sand deposits and contains a layer of clasts as large as 10 mm; this context is provisionally interpreted to represent a blowout that was filled in with sediment from an older context. Supporting this hypothesis, the flake recovered in this context has a luster suggesting wind abrasion on a deflated surface. This single flake was not assigned a component number because of the high probability it represents redeposited cultural material.

Component 1 (C1) consists of four flakes and more than 1490 highly fragmented faunal remains, including highly degraded maxilla and tooth enamel fragments of a large Cervidae, probably wapiti (*Cervus canadensis*) or caribou (*Rangifer tarandus*), in what is provisionally identified as a Btb4 horizon comprised of lamellar bands (following Holliday 2004). This context follows a sloping dune bed, appearing 20 cm below C2 in Figure 12; however the C1 cultural material was recovered approximately 50 cm below C2 in an adjacent test unit. Dispersed charcoal recovered from this context yielded an AMS date of 9620 ± 50 ^{14}C BP (Table 4).

Test excavations conducted at HEA-454 highlight the potential of the Susitna dune for recovering deeply buried, datable cultural material spanning the entire Holocene (Blong 2011). However, test excavations also highlight the complex sedimentary and pedogenic processes on the Susitna dune, potentially affecting archaeological contexts. The C3 context is fairly straightforward across the site, and represents an LH occupation of the dune following deposition of the Devil tephra, radiocarbon dated in the middle Susitna valley to approximately 1500-1300 cal BP (Dixon and Smith 1990). C3 contains the densest deposits, with a lithic artifact density (LAD) of 13.1/50 cm^2, as well as a charcoal feature, suggesting more intensive use of the site during this time. Minimal cultural material was recovered on top of the Watana tephra in areas where the Devil tephra was ephemerally expressed. With further investigation, it is possible that an additional LH cultural component may be defined at the contact of the Devil and Watana tephras.

We recovered little cultural material from C2 (LAD 0.6/50 cm^2) and C1 (LAD 0.25/50 cm^2), and radiocarbon dates associated with these components are not from cultural features. These data suggest an ephemeral EH and MH occupation of the site, possibly a short-term camp or activity area, but without more substantial lithic and faunal assemblages and radiocarbon dates from cultural features, it is difficult to interpret the nature and timing of these occupations. C1 in particular needs to be further explored; additional research is needed to ensure that an as yet unrecognized post-depositional process has not disturbed archaeological deposits. The single flake recovered from redeposited sediments in between C2 and C1 also hints at an older occupation; while the associated radiocarbon date is stratigraphically inconsistent, this context is overlain by C2, indicating an upper limiting date of 7700 cal BP for deposition of this unit. More importantly, this single flake in potentially redeposited sediments reinforces that the dune is a dynamic aeolian context.

The C1 context is poorly understood; the Bt horizons at the site have the appearance of clay lamellae, representing clay translocated down through sandy sediments and deposited in fine sand at the top of dune sand bands (Birkeland 1999). The Bt horizons sometimes exhibit brown (10YR 4/3) mottling, possibly representing accumulations of translocated humic material or pedogenic Fe. It is common in the region for humic material to elluviate down the profile as a consequence of Spodosol formation (Ping et al. 1989).

An alternative explanation for these Bt horizons is that they represent clay translocated down the profile and deposited on buried soils representing short-term vegetation growth and soil development on a stabilized dune surface. A potentially analogous sequence of weakly developed Ab horizons has been documented at the Keystone Dune site in the Tanana Valley (Reuther 2013). A buried A horizon would explain the presence of sparse charcoal and brown mottling observed in these horizons, as well as the presence of C1 faunal material recovered *in-situ* from a Btb4 horizon. Typically, buried soil horizons are recognized by increased clay content, especially in the upper part of the buried B horizon, and an abrupt upper-horizon boundary (Birkeland 1999). The horizons described here exhibit an increase in clay, but they typically do not have an abrupt upper boundary. The Bt horizons represented in Figure 12 dip steeply to the south, and are represented lower in the southern wall than the northern wall. If the Bt horizons do represent a buried surface, then it was a steeply-sloping surface. Given the lack of unequivocal data for buried A horizons, the most parsimonious explanation with the current level of data is that the clay bands represent Bt horizons. It is possible that the faunal material was naturally deposited on fine sand in a period of dune building, and translocated clay accumulated at this contact post-depositionally, creating the appearance of a buried surface.

Other Susitna Dune Sites

Because of the potential for Susitna dune archaeological deposits to inform on the earliest inhabitants of the study area, we excavated 22 50-cm^2 test units at 30 m intervals along the dune ridge, and recovered cultural material from 11 of these. We placed an additional five 50-cm^2 test units adjacent to test units where cultural material was recovered. Test excavations along the dune revealed a profile similar to that at HEA-454 at most locations. Test excavations resulted in the discovery of five sites (HEA-507, HEA-508, HEA-509, HEA-510, and HEA-

511) (Figure 11). We also conducted test excavations at two previously recorded sites (HEA-234 and HEA-235) (Figure 11), to determine if there were subsurface cultural deposits. Both of these sites have been significantly disturbed by wind erosion and deflation.

From each of the seven sites described above, we recovered lithic assemblages in a silt loam A horizon on top of an EA horizon formed on the Devil tephra or from rodent disturbed contexts with uncertain cultural component association. All material recovered from on top of the Devil tephra is identified as dune C3 representing LH occupation of the site (after 1500-1300 cal BP), regardless if cultural material was recovered below this context. The only site with a significant amount of cultural material was HEA-508, where we also recovered two debitage pieces and a biface from an A/Eb2 horizon developed on a reworked sand and tephra deposit. This context correlates stratigraphically to C2 at Susitna Dune 1, so probably represents an MH occupation of the site. None of the test units recovered material in bedded sand dune deposits like in C1 at Susitna Dune 1 (Table 5). Taken together, there is typically sparse cultural material on the Susitna dune, suggesting ephemeral use in short-term camps or activity sites; however, further testing may identify additional concentrations.

Table 5. Excavation information for Susitna dune sites.

Site	Units excavated	Stratigraphic provenience	Material recovered by dune component	Lithic artifact density /50 cm^2
Susitna Dune 3 (HEA-507)	Five 50 cm^2	Surface	Surface: 3 debitage, 2 tools	-
		A horizon and contact with EA formed on Devil tephra	C3: 6 debitage	C3: 1.2
		Rodent-disturbed sediments	Rodent: 4 debitage, 1 tool, 1 bone fragment	-
Susitna Dune 4 (HEA-508)	Six 50 cm^2	A horizon and contact with Devil tephra	C3: 123 debitage, 9 tools, 2 bone	C3: 22
		A/Eb2 formed on reworked sand and tephra	C2: 2 debitage, 1 tool	C2: 0.5
Susitna Dune 5 (HEA-509)	Two 50 cm^2	A horizon and contact with EA formed on Devil tephra	C3: 1 debitage, 6 bone fragments	C3: 0.5
		Rodent-disturbed sediments	Rodent: 4 debitage, 13 bone fragments	-
Susitna Dune 6 (HEA-510)	One 50 cm^2	A horizon and contact with EA formed on Devil tephra	C3: 4 debitage	C3: 4
Susitna Dune 7 (HEA-511)	Two 50 cm^2	A horizon and contact with EA formed on Devil tephra;	C3: 1 debitage	C3: 0.5
		Rodent-disturbed sediments	Rodent: 1 debitage	-
HEA-234	One 50 cm^2	Surface	Surface: 8 debitage, 3 tools	-
		A horizon and contact with EA formed on Devil tephra	C3: 1 debitage, 1 tool	C3: 2
HEA-235	Two 50 cm^2; One 1 m^2	Surface	Surface: 3 tools	-
		A horizon and contact with EA formed on Devil tephra	C3: 4 debitage	C3: 0.7
		Disturbed sediment	Disturbed: 2 debitage	-

Susitna Dune Geomorphological and Tephrochronological Sampling

During testing on the Susitna dune, we observed round to sub-round cobbles eroding out of the leeward side of the dune. This suggests that the dune is a topographic dune (e.g., Waters 1992). We collected GPS data marking the location of these exposures, excavated two adjacent bank cuts to expose the contact of the dune sand and underlying glacial meltwater drift deposits, and collected two OSL samples from this contact (Figure 11). The presence of sub-round to round gravels in a gravelly-sand horizon suggests the dune is underlain by an esker-like landform, similar to eskers mapped just west of the dune (Smith et al. 1988). The shape of the dune suggests it was formed by a prevailing wind regime originating from the north, possibly related to katabatic winds blowing off of still-receding glaciers covering the Monahan Flat 16-13,000 cal BP The aeolian sediment that formed the Susitna dune likely originated from glacial outwash deposited on the Monahan Flat.

To better understand the timing of deglaciation and dune formation in the study area, we dated one OSL sample collected from the contact of the dune sediments and underlying glacial drift. This analysis produced a date of 16,865 ± 1010 (Table 6), suggesting that dune sands were accumulating on the southern edge of Monahan Flat by this time. The Devil tephra was thicker on the dune compared to elsewhere in the study area, possibly the result of the accumulation of aeolian transported tephra from across Monahan Flat. Because the Devil tephra was so well-represented on the dune, we collected a sample at HEA-509 for geochemical analysis at USGSMP (Alaska Tephra Database no. AT-2790).

Table 6. Optically stimulated luminescence (OSL) age and associated chronological data for quartz extracts for an eolian sand, Susitna dune, upper Susitna River basin.

Analysis	**Results**
Field sample number	SDOSL1
Laboratory number	UIC3485
Fraction analyzed (microns)	150-250
Method[a] and mineralogy	MAR, quartz
Equivalent dose (Grays)	32.39 ± 1.60
U (ppm)[b]	1.6 ± 0.1
Th (ppm)[b]	5.2 ± 0.1
K (%)[b]	1.23 ± 0.02
Cosmic dose (Grays/ka)[c]	0.21 ± 0.02
Dose rate (Grays/ka)[d]	1.92 ± 0.10
Apparent OSL Age (ka)[e]	16,865 ± 1010

[a] MAR=Multiple aliquot regenerative dose (Jain et al. 2003 under blue light (Bl) excitation (470±20 nm).
[b] U, Th, and K content determined by ICP-MS by Activation Laboratory Inc. Ontario, Canada.
[c] From Prescott and Hutton (1994).
[d] Includes moisture content estimate of 10 ± 3%.
[e] All ages are calculated from the datum year AD 2000 and errors include systematic and random errors in a quadrature (S. Forman personal communication 2013).

Susitna River 3 (HEA-455)

Susitna River 3 is located at 860 masl, on a prominent bedrock knoll overlooking Monahan Flat to the north and the Susitna River to the east (Figure 10). Vegetation at the site is shrub tundra; shrub birch is abundant; willow (*Salix spp.*), blueberry, dwarf Labrador tea, and graminoids (Poaceae) are common. The site has a broad surface lithic scatter with concentrations of calcined and burned faunal remains, covering an area of ~200 m x 80 m, primarily exposed in an off-highway vehicle (OHV) trail. Lithic tools collected from the surface include notched and lanceolate projectile point forms, microblades, and scrapers.

We excavated four 1-m^2 and four 50-cm^2 test units across the site, and identified three cultural components. The stratigraphy at the site is shallower than on the Susitna dune; however, they have similar stratigraphic sequences (Figure 13). LOI analysis of sediment samples from test unit N179 E107 shows an expected peak in OC in the A horizon, followed by a decrease in the EA horizon, an increase in the B horizon, and a slight relative increase in the Ab2 horizon (Figure 13). The Devil tephra is inconsistently represented across the site and appears to have been disturbed by OHV traffic and recent human use of the landform. In test units with hearth features, underlying natural stratigraphic horizons are often disturbed. Physical processes associated with freezing and thawing of sediments have affected archaeological context at the site. Cryoturbation features were present in most test units, including dome-shaped “hummocks” that distorted soil horizons, and irregular and broken horizons and textural bands (Fitzpatrick 1997; Schunke and Zoltai 1988). Sediment samples 4, 3a, and 2 from test excavation N179 E107 were subsampled for tephra geochemistry analysis at TAMUEML.

Component 3 (C3) consists of approximately 160 highly fragmented faunal remains and 1456 lithics recovered from the A horizon, Devil tephra, and in some cases its contact with the underlying B horizon formed on the Watana tephra. It was necessary to combine cultural material from these contexts into

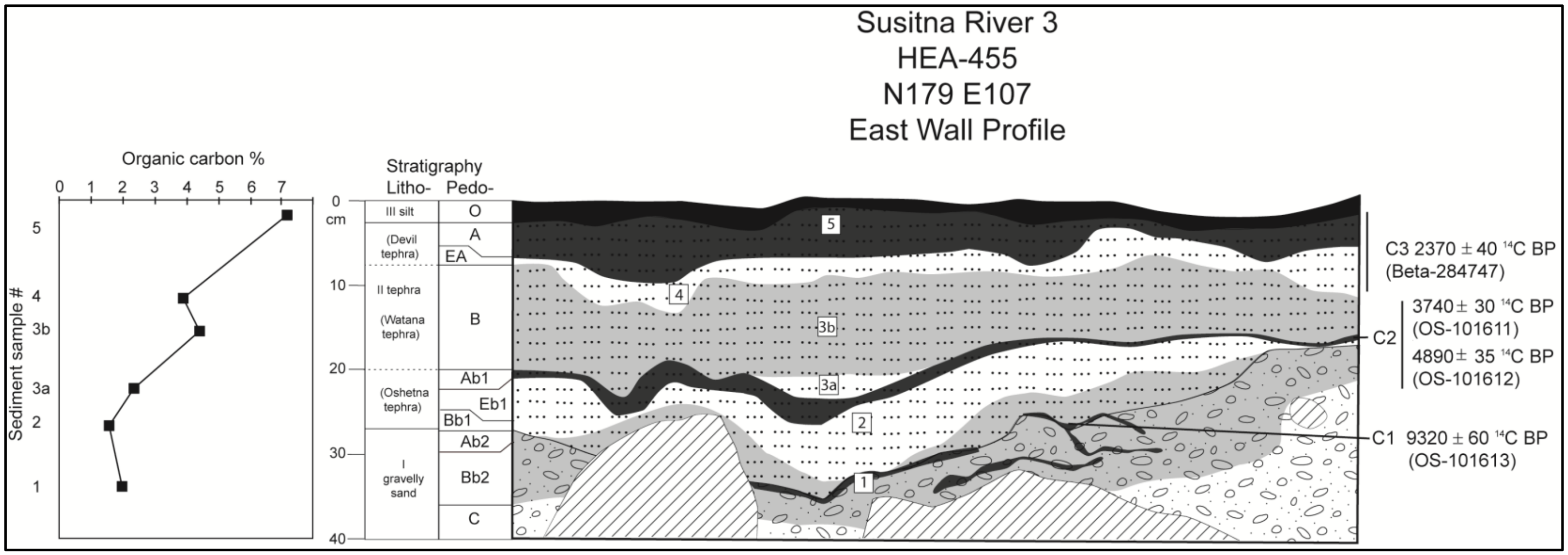

Figure 13. Susitna River 3 (HEA-455) profile.

C3, representing occupation of the site following deposition of the Watana tephra, because in many test units the A horizon, Devil tephra, and associated cultural material were mixed together by the disturbances discussed above.

Test unit N190 E84 was placed at the peak of the HEA-455 landform, in an area with outcropping bedrock and very shallow sediments. In this test unit, the Devil tephra is weakly expressed as a broken horizon underlying the O/A horizon. Also underlying the O/A horizon across most of the unit is a shallow, basin-shaped charcoal feature (Feature 1) directly overlying the Watana tephra. In the few places where the Devil tephra is present, the charcoal feature separates the Devil and Watana tephras. The upper portion of the Watana tephra contains charcoal and is stained with organic material. Charcoal from Feature 1 yielded an AMS date of 2370 ± 40 ^{14}C BP (Table 4). Artifacts recovered from the A horizon and charcoal feature in this test unit were assigned to C3.

Component 2 (C2) consists of approximately 600 highly fragmented faunal remains (Mueller 2015) and 3433 lithics primarily recovered from a charcoal-rich paleosol at the contact of the Watana tephra and underlying Oshetna tephra. Dispersed charcoal from this paleosol yielded an AMS date of 4890 ± 35 ^{14}C BP (Table 4). In test unit N74.5 E129.5 on the southern edge of the site, we excavated a charcoal hearth feature (Feature 2) from the C2 context. This feature contained fire-cracked rock and a dense concentration of faunal remains and lithic artifacts, including a side scraper, two end scrapers, three notched point fragments, and a backed knife. Charcoal from this feature yielded an AMS date of 3740 ± 30 ^{14}C BP (Table 4). The activity that created this hearth feature appears to have disturbed underlying sediments, and we did not observe the Oshetna tephra in this test unit. In test unit N190 E84, the Oshetna tephra also was not represented. Cultural material was recovered from a silt horizon underlying the Watana tephra and overlying the gravelly sandy-loam regolith sediments comprising the bedrock horizon. This material has been provisionally assigned to C2 found under the Watana tephra in other test units at the site. Component 1 (C1) consists of 706 lithics and 5 highly fragmented faunal remains recovered from the contact of the Oshetna and underlying paleosol formed on gravelly sand regolith sediment. Dispersed charcoal from this context yielded an AMS date of 9320 ± 60 ^{14}C BP (Table 4).

There is evidence for human occupation at Susitna River 3 from the EH through LH. C3 represents an LH occupation of the site (associated with a date of 2682-2329 cal BP but also representing occupation after deposition of the Devil tephra at approximately 1500-1300 cal BP) with artifact density (LAD 72.8/50 cm^2) and a charcoal feature suggesting somewhat intensive use of the site possibly as a residence site. C2 represents a MH occupation of the site (5711-3984 cal B.P), with a high artifact density (LAD 171.7/50 cm^2) and hearth feature suggesting intensive occupation, possibly as a residence site. Diagnostic notched projectile points associated with C2 indicate this occupation falls within the Northern Archaic tradition. C1 represents an EH occupation of the site

(10,690-10,300 cal BP), with artifact density (35.3/50 cm^2) and lack of cultural features suggesting a less intensive occupation of the site, possibly as a short-term camp or activity area. Based on LAD and the number and nature of cultural features in the site areas excavated to date, the most intensive occupation at Susitna River 3 was during the MH, while the LH occupation was more intensive than the EH.

Susitna River 2 (HEA-502)

HEA-502 is situated at 813 masl, on a northwest to southeast trending glacial drift landform 100 m long and 20 m wide, overlooking the Susitna River to the south and east (Figure 10). Vegetation at the site is shrub tundra; shrub birch and blueberry are abundant; willow, cranberry, bearberry, Labrador tea, and crowberry are common; spruce is rare. On steeper slopes willow and river alder (*Alnus rugosa*) are common, and spruce is rare. The site has a small lithic scatter eroding from the southeastern tip of the landform.

We excavated seven 50-cm^2 test units concentrated on the southeastern edge of the landform overlooking the Susitna River and identified one cultural component. Stratigraphy at the site consists of a typical O-A-EA-B sequence underlain by an EAb1 and Bb1 buried profile. Loss-on-ignition analysis was not conducted at this site. Glacial drift underlying the site consists of well-sorted, rounded gravels suggesting a glacial outwash formation (Figure 14, Table 7). The Oshetna tephra is not well expressed at the site, and there is no distinct charcoal-rich Ab horizon formed on the Oshetna. The Bb1 horizon represents weathering of the drift deposit underlying the Oshetna tephra. Based on the lack of humic material or charcoal at this contact, this is provisionally interpreted to represent elluviated material from the EAb1 horizon, but it could represent a buried soil formed on drift sediments. Component 1 (C1) at the site consists of 53 lithics recovered from the modern A horizon and its contact with the underlying Devil tephra. There are no radiocarbon dates associated with this material. C1 represents a LH occupation of the site (after deposition of the Devil tephra approximately 1500-1300 cal BP), with low artifact density (LAD 7.6/50 cm^2) and lack of cultural features in the areas of the site excavated to date suggesting ephemeral use as a short-term camp or activity area.

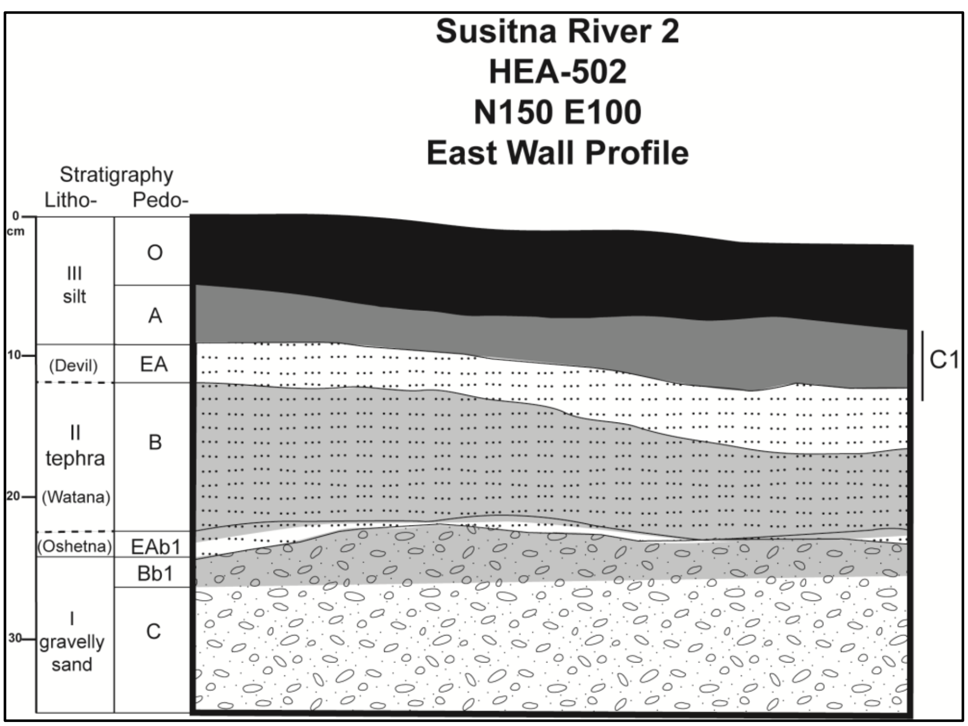

Figure 14. Susitna River 2 (HEA-502) profile.

Table 7. Mineral soil descriptions for Susitna River 2 (HEA-502) N150 E100 east wall profile.

PU[1]	Description	LU[2]
A	Dark gray (10YR 4/1); silty loam with abundant organics; weak fine platy structure; frequently has abundant charcoal; clear wavy boundary	III
EA	Gray (7.5 YR 6/1), with common large white (7.5 YR 8/1) and pink (5YR 8/3) mottles; silty loam with minor amount of organics; weak fine platy structure; clear wavy boundary (Devil tephra)	II
B	Reddish brown (5YR 4/3); sandy loam with common pebble-size clasts; weak fine subangular blocky structure; common faint coatings on rootlets and clasts; abrupt wavy boundary (Watana tephra)	II
EAb1	Gray (7.5YR 6/1); sandy loam with common pebble-sized clasts; weak fine platy structure; abrupt wavy boundary (Oshetna tephra)	II
Bb1	Brown (7.5YR 5/3); coarse gravelly sand with well-sorted subround to round pebble to cobble sized clasts; structureless; clear wavy boundary	I
C	Brown (10YR 5/3); coarse gravelly sand with well-sorted subround to round pebble to cobble sized clasts; structureless; boundary unknown	I

[1]Pedostratigraphic unit
[2]Lithistratigraphic unit

Butte Creek 1 (HEA-499)

Butte Creek 1 is located at 772 masl, on a long, northwest to southeast trending esker, overlooking the Butte Creek drainage (Figure 10). Vegetation at the site is shrub tundra; shrub birch is abundant; crowberry, lowbush cranberry, blueberry, and dwarf Labrador tea are locally abundant; fireweed (*Epilobium angustifolium*) and willow are common; white spruce, black spruce, bearberry (*Arctostaphylos uva-ursi*), and graminoids are rare. The site has a broad surface lithic scatter with concentrations of calcined bone, covering an area of ~200 m x 10 m, primarily exposed in an OHV trail along the length of the esker.

We excavated four 50-cm^2 test units near a surface concentration of lithics and bone on the northern edge of the site and identified two cultural components. A typical profile at the site consists of an O-A-EA-B profile similar to those observed elsewhere in the study area (Figure 15). LOI analysis shows a peak in OC in the A horizon, a decrease in OC in the underlying EA horizon, a slight increase in OC in the underlying B horizon, a decrease in OC in the Ab1 horizon, and a significant drop-off in OC in the remaining profile.

The stratigraphy at Butte Creek 1 differs from a typical profile in the study area in that sediments underlying the Watana tephra have been significantly affected by human activity. Directly underlying the Watana tephra is a thin organic and charcoal horizon formed on gravelly sand sediment similar to that comprising the C horizon esker sediments that the site sits on. Directly underneath these esker sands in adjacent test units 2 and 4 are a dense charcoal feature (Feature 1) and a very dense calcined bone and fire-cracked rock feature (Feature 2).

The Oshetna tephra is expressed as a thin horizon, compressed and reddened in places from the heat of the overlying hearth feature. Underlying the Oshetna tephra are gravelly sand esker sediments. The sub-Watana stratigraphic sequence is interpreted as human occupation of the site following deposition of the Oshetna tephra, creating the two features on top of the

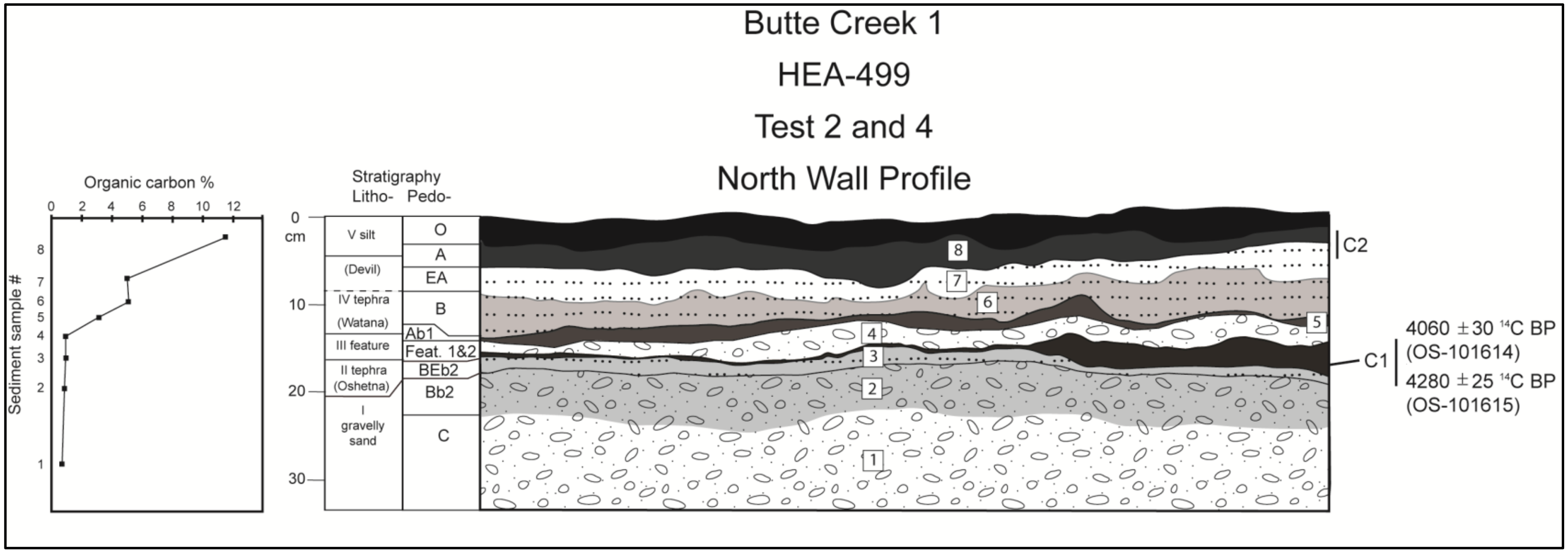

Figure 15. Butte Creek 1 (HEA-499) profile.

Oshetna. Following this, gravelly sand esker sediment was deposited on top of the two features, likely related to human activity, but possibly from colluvium washing down the esker slope. A thin organic horizon formed on the gravelly sand unit, minimally representing a surface fire, but possibly representing longer-term stability and paleosol formation. Following this, the Watana tephra was deposited. The stratigraphy in adjacent test units 1 and 3 mirrors that of test units 2 and 4, including burned sediment and dense bone concentrations on top of the Oshetna tephra, possibly representing an extension of Feature 2 across the site.

Component 2 (C2) at the site consists of approximately 3100 fragments of animal bone (Mueller 2015) and 50 lithics, in the A horizon and at its contact with an EA horizon formed on the Devil tephra. Component 1 (C1) consists of approximately 10,600 faunal-remain fragments (Mueller 2015) and 769 lithics, primarily from features 1 and 2 above. Charcoal from Feature 1 yielded an AMS date of 4060 ± 30 ^{14}C BP; charcoal from Feature 2 yielded an AMS date of 4280 ± 25 ^{14}C BP (Table 4).

Most of the faunal remains recovered from C1 came from features 1 and 2. Sixteen of the faunal specimens from C1 were identified to the element represented, and five were identified to order. The remaining specimens were too fragmentary to identify to any element or taxon. Of the 16 identified specimens, eleven were identified as Class Mammalia. Four specimens represent Order Artiodactyla, probably caribou, and one specimen was identified to Order Rodentia, probably North American beaver (*Castor canadensis*) (Mueller 2015).

There is evidence for human occupation at Butte Creek 1 from the MH through LH. C2 represents a LH occupation of the site (after deposition of the Devil tephra approximately 1500-1300 cal BP), with artifact density (LAD 12.5/50 cm^2) and lack of cultural features suggesting use as a short-term camp or activity area. C1 represents a MH occupation of the site (4867-4830 cal BP), with artifact density (LAD 192.3/50 cm^2) and two significant features suggesting intensive site use, likely as a processing location. Based on LAD and the number and nature of cultural features from the areas of the site excavated to date, the most intensive occupation at Butte Creek 1 was in the MH.

Snodgrass Lake 1 (HEA-500)

HEA-500 sits at 790 masl, on the southern edge of a small kame-like landform south of Snodgrass Lake (Figure 10). HEA-500 overlooks the Butte Creek drainage and the confluence of Butte Creek and the Susitna River to the southeast. Vegetation at the site is shrub tundra; shrub birch is abundant; crowberry, lowbush cranberry, blueberry, bearberry, and dwarf Labrador tea are common; willow and spruce are rare and confined to the slopes of the landform. The site has a small lithic scatter eroding out of a blowout on the southern edge of the landform.

We excavated two 50-cm^2 test units on the southwestern edge of the landform and identified one cultural component. A typical profile at the site is a typical O-A-EA-B-AEb1-Bb1 sequence. Loss-on-ignition analyses were not conducted on sediments from this site. Component 1 (C1) consists of three lithics recovered from the contact of a silt loam A horizon and underlying AE horizon formed on the Devil tephra. There are no radiocarbon dates from this context, but its stratigraphic position suggests a LH occupation of the site (after deposition of the Devil tephra approximately 1500-1300 cal BP). In addition, a single fragmented, unidentifiable animal bone and several .22 caliber shell casings were recovered in a sandy organic mat overlying the modern A horizon. This context was interpreted as an over-thickened organic mat containing redeposited sand from the adjacent blowout, representing modern hunting activity. C1 represents LH occupation of the site, with low artifact density (LAD 1.5/50cm^2) and lack of cultural features in the areas of the site excavated to date suggesting ephemeral use of the site as a short-term camp or activity site.

West Fork Susitna 1 (HEA-506)

West Fork Susitna 1 sits at 778 masl, on the northeastern edge of a glacial outwash landform overlooking the West Fork Susitna River to the east (Figure 10). Vegetation at the site is shrub tundra; shrub birch and blueberry are abundant; cranberry, crowberry, dwarf Labrador tea, and willow are common;

spruce (primarily white spruce) is rare. We excavated two 50-cm^2 and one 1-m^2 test units and identified two cultural components.

A typical profile at the site consists of an O-A-EA-B-AEb1-Bb1 sequence, similar to that at HEA-502 (Figure 16). Loss-on-ignition analysis of sediment samples show an OC peak in the A horizon, followed by a decrease in the EA, increase in the B, then a decrease in the AEb1 (Figure 16). The glacial outwash formation the site sits on is capped with coarse sand and pebbles, probably representing post-glacial fluvial deposits from West Fork Susitna River. Component 2 (C2) at the site consists of 65 lithics recovered from the A horizon and its contact with the Devil tephra. The Devil tephra was sometimes ephemerally expressed, and some cultural material was recovered from the contact of the A horizon and underlying Watana tephra. All of this material was considered to be part of C2.

Component 1 (C1) at the site consists of nine lithics recovered from an AEb1 horizon formed on the Oshetna tephra, directly underlying the Watana tephra. Dispersed charcoal from the Component 1 context yielded an AMS date of 4510 ± 25 ^{14}C BP (Table 4). West Fork Susitna 1 represents the furthest north location we tested for this research, so we collected a sample of the Devil tephra (sediment sample 4) to compare to tephras from further south. This sample was geochemically analyzed at USGSMP (Alaska Tephra Database # AT-2791).

C2 represents an ephemeral LH occupation of the site (after deposition of the Devil tephra approximately 1500-1300 cal BP, but possibly containing

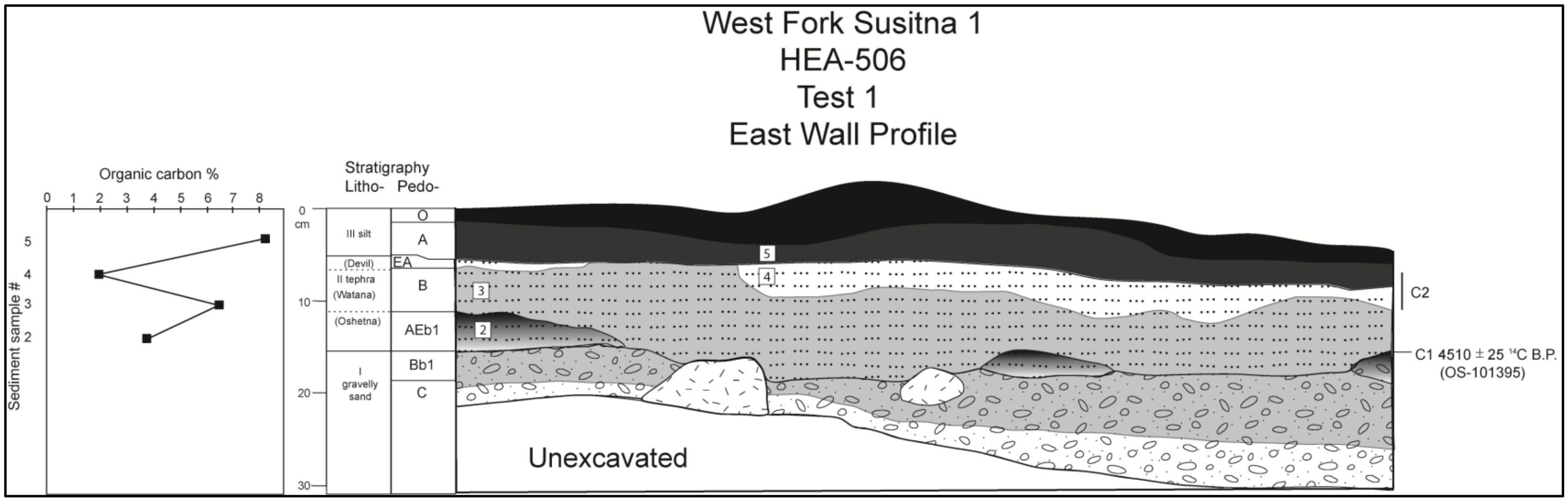

Figure 16. West Fork Susitna 1 (HEA-506) profile.

cultural material deposited after deposition of the Watana tephra approximately 4200-3700 cal BP), with artifact density (LAD 10.8/50 cm^2) and lack of cultural features in the areas of the site excavated to date suggesting the site served as a short-term campsite or activity location. C1 represents an ephemeral MH occupation (5299-5050 cal BP), with low artifact density (LAD 1.5/50 cm^2) and lack of cultural features suggesting less intensive use, also as a short-term campsite or activity location.

Alpine Creek 8 (HEA-460)

HEA-460 is located at 1340 masl, on a slightly elevated moraine feature alongside a small tributary to Alpine Creek, on the west side of the Alpine Creek valley (Figure 10). Vegetation at the site is alpine tundra; graminoids, herbaceous taxa, and bryophytes are abundant; ericaceous dwarf shrubs are common; willow is rare and confined to drainages. There is an abundance of knappable grayish-green fine-grained meta-volcanic or tuffaceous argillite toolstone in pebble- to boulder-size gravels throughout this valley. The site has a broad surface lithic scatter primarily concentrated in a 50-m^2 area, but with surface lithics visible as far as 100 m south of this concentration.

We excavated ten 50-cm^2 test units across the densest part of the surface scatter on the southern edge of the landform. The soil profile at Alpine Creek 8 is a departure from the typical sequence observed at lower elevations, consisting of a modern A-B profile overlying a possible buried soil overlying gravelly sandy clay glacial drift deposits (Figure 17, Table 8). The A1 and Ab1 horizons have 6% OC in a ~10-cm thick horizon. These pedostratigraphic units have platy structure, common in surface mineral horizons affected by freezing and thawing (Ping et al. 2008). The Ab1 horizon is not present in all test units, but appears to represent a discontinuous buried A horizon. The B1 and B2 horizons have illuvial characteristics including subangular blocky structure, clay accumulation, clay coatings on clasts and roots, and exhibit a decrease in percent OC. The gray to grayish brown color of the B1 and B2 horizons in Figure 6 could represent development of a cambic B horizon, common in soils formed in subarctic tundra settings (Fitzpatrick 1997). Alternatively, the gray color could be related to a high degree of wetness from permafrost acting as a barrier to movement of water, resulting in a gleyed soil profile. These horizons fit the criteria for gleyed horizons in that they are neutral in color with a chroma of 2 or less (Birkeland 1999; Fitzpatrick 1997). In most test units there was a very dark gray horizon overlying glacial drift with granular structure and exhibiting an increase in percent OC; this was interpreted to represent an Ab2.

Sediment samples six through two were analyzed at 20-40x under a dissecting microscope; samples four, three, and two have abundant tephra pumice in them, contrasting greatly with samples six and five, which had very little pumice. The presence of tephra pumice in these stratigraphic units suggests that one or more of the tephras deposited at lower elevations in the study area was deposited at Alpine Creek 8 and significantly reworked, either by

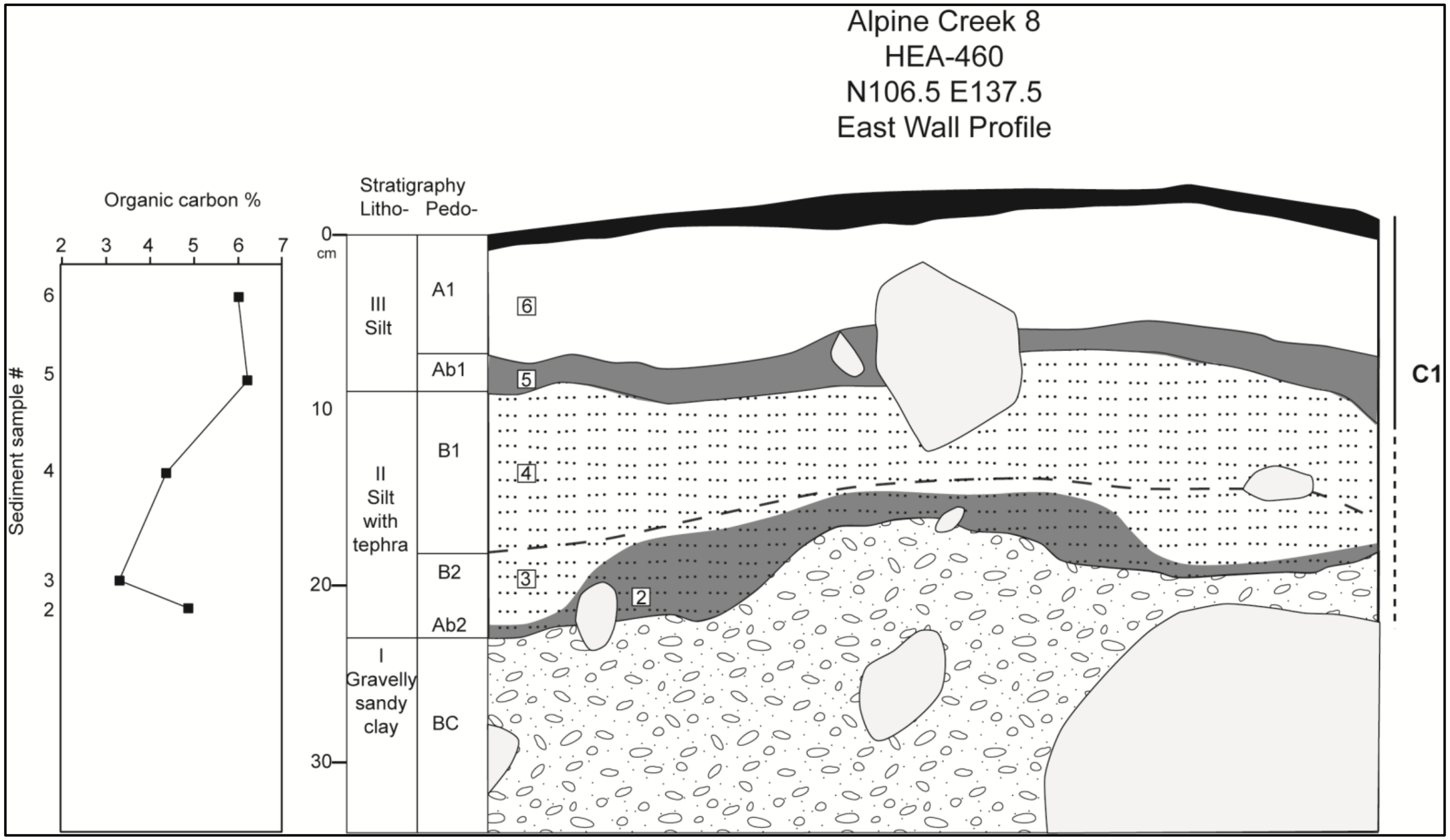

Figure 17. Alpine Creek (HEA-460) profile.

Table 8. Mineral soil descriptions for Alpine Creek 8 HEA-460 N106.5 E137.5.

PU[1]	Description	LU[2]
A1	Brown (10 YR 4/3); silt loam with humus; weak fine platy structure; clear wavy boundary	III
Ab1	Very dark gray (10YR 3/1); silt loam to silt clay loam; weak fine platy structure; clear wavy boundary	III
Bg1	Gray (10YR 5/1); silty clay loam with abundant tephra pumice and common angular to subangular pebble clasts; weak fine subangular blocky structure; common discontinuous clay coatings on clasts and roots; clear wavy boundary	II
Bg2	Grayish brown (10YR 5/2); silty clay loam with common pumice and common angular to subangular pebble clasts; weak fine subangular blocky structure; common discontinuous coatings on clasts and roots; clear wavy boundary	II
Ab2	Very dark gray (10YR 3/1); silty clay loam with common pumice and abundant angular to subangular pebble and cobble clasts; weak fine granular structure; abrupt wavy boundary	II
BC	Light grayish brown (2.5 Y 6/2); sandy clay with abundant pebble to boulder clasts; structureless; few discontinuous coatings on clasts and roots; boundary unknown	I

[1]Pedostratiographic unit
[2]Lithistratographic unit

aeolian action, or possibly by outwash, alluvial, or fluvial action correlated with Holocene expansion and retraction of alpine glaciers (e.g., during the Neoglaicial period or Little Ice Age). There are as many as two buried A horizons at Alpine Creek 8; these may correlate with paleosol development on top of glacial till and on the Oshetna tephra at lower elevations, but we did not recover material to radiocarbon date these horizons, so their age is not known. Cryoturbation features at the site include hummocks and frost heaving, a process that appears to be responsible for significant artifact displacement at the site; we commonly encountered small debitage underneath frost-heaved cobbles in gravelly drift sediments.

A total of 1306 lithic artifacts were recovered from the surface down into drift. The dominant toolstone in the assemblage is available in the glacial drift that the site sits on and in the surrounding valley. The densest subsurface deposits came from the eastern portion of the site. The one exception to this is N108 E125, the most productive test unit on the western portion of the site. In general, the stratigraphy on the eastern portion of the site was as represented in Figure 6. On the western portion of the site the stratigraphy was typically shallower, had more reddish-yellow mottling, and was more affected by cryoturbation. Once again, the exception to this is N108 E125, which had the deepest profile at the site. We did not encounter any cultural features, and there was no charcoal clearly associated with cultural material, possibly related to the lack of naturally occurring trees or shrubs to burn.

The majority of the lithics were recovered from the A1 horizon (Figure 18). There is a peak in cultural material in the B horizon on the western portion of the site, but this material was almost exclusively from test unit N108 E125, which had extensive evidence of cryoturbation, including a large hummock that lifted B horizon sediments up into the A1 horizon. Because most of the cultural material at the site came from the A1 horizon, and occurred above potentially reworked tephra horizons, all cultural material at the site is provisionally assigned to C1, a LH occupation of the site, with artifact density (LAD 130.6/50 cm^2) suggesting intensive use of the site as a quarry camp.

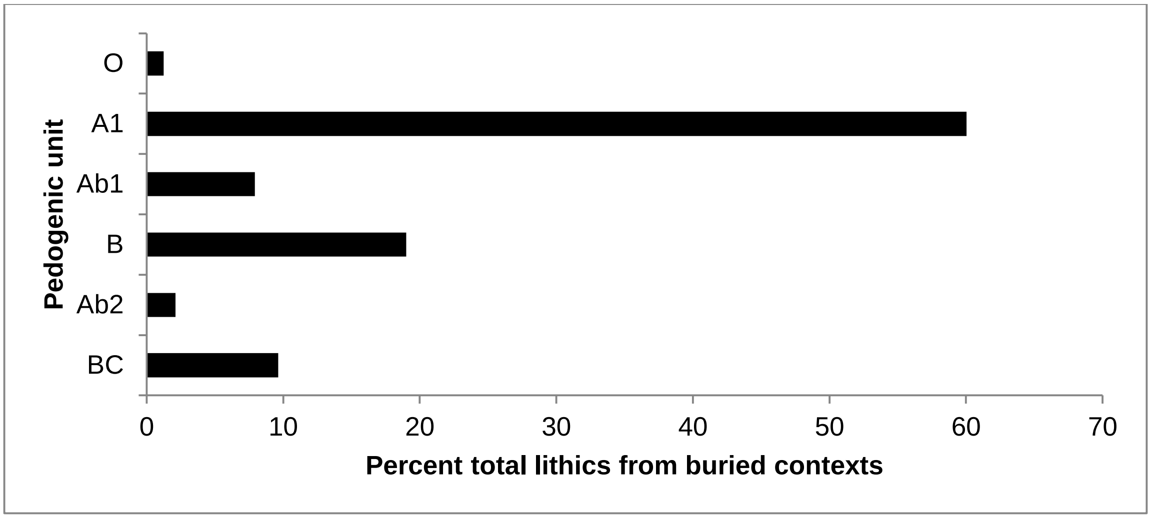

Figure 18. Alpine Creek (HEA-460) chart showing percent of total lithics recovered from subsurface contexts by pedogenic unit.

Windy Creek 1 (HEA-505)

Windy Creek 1 sits at 1070 masl on a flat bench south of Windy Creek, southeast of a small-unnamed lake, on the northeast side of a small creek draining the mountains to the south (Figure 10). Vegetation at the site is alpine tundra; shrub birch is locally abundant; blueberry, moss, lichen, short-leaf Labrador tea, and crowberry are common; cranberry, bearberry, grass, and bunchberry are rare.

The site consists of a broad lithic scatter covering an area 100 m by 30 m. The site was rutted with crisscrossing game trails (probably caribou); much of the lithic assemblage was exposed in these trails. We did not conduct test excavations, because the game trails went down to gravel, and it was apparent that there was very little deposition at the site (approximately 10-20 cm). The sediment at the site appeared similar to that at Alpine Creek 8 in that it is a dark, organic-rich silt. We collected all surface lithics as one component consisting of 241 lithics. The Windy Creek 1 assemblage is from a surface context and has no associated radiocarbon or tephrochronological age; however, the site may represent a LH occupation of the Clearwater Mountains, similar to Alpine Creek 8. It is not useful as a temporal marker of landscape use in the Clearwater Mountains, but it is still useful as a representation of human use of alpine tundra landscapes in the uplands of the Clearwater Mountains.

Devil Tephra Analysis

Subsamples of Devil tephra were analyzed from sediment sample 4 at Susitna River 3 (HEA-455-S4) (Figure 13), sediment sample 4 at West Fork Susitna 1 (HEA-506-S4) (Figure 16), and a sample from an EA horizon underlying the modern A horizon collected at Susitna Dune 5 (HEA-509-S4). Table 9 provides a physical description of the Devil tephra samples. The Devil tephra is the uppermost tephra deposit in the study area, and typically occurs as an unoxidized horizon, with Munsell colors ranging from gray to white to pink, and a silt loam field texture. All three Devil samples have rhyolite matrix glass containing 72.32-72.79 wt % SiO_2 (Figure 19), and uniform glass composition with relatively low standard deviations (Table 10). These physical and geochemical characteristics are similar to the Devil tephra described in the middle Susitna basin (Table 2). A single radiocarbon date underneath the Devil tephra at Susitna River 3 indicates deposition after 2427 cal BP.

Table 9. Physical description of upper Susitna tephra deposits.

Sample	Regional correlate[1]	Grain size[2]	Pumice color	Pumice Munsell color	Relative pumice glass shard frequency
HEA-509-S4	Devil	Very fine to coarse ash	White to creamy white	10YR 8/2, some grading to 5YR 6/4	Abundant
HEA-506-S4	Devil	Very fine to coarse ash	White to creamy white	10YR 8/2, some grading to 5YR 6/4	Abundant
HEA-455-S4	Devil	Very fine to coarse ash	White to creamy white	10YR 8/2, some grading to 5YR 6/4	Abundant
HEA-455-S3	Watana	Very fine to coarse ash	Creamy white	5YR6/4, 5YR4/4 (oxidized)	Abundant
HEA-455-S2	Oshetna	Very fine to coarse ash	White	10YR 6/2, 10YR 7/4 (oxidized)	Rare

[1] Tephras in this study correlated to tephras identified in the middle Susitna basin (Dilley 1988; Dixon and Smith 1990).
[2] Grain size classification following White and Houghton (2006).

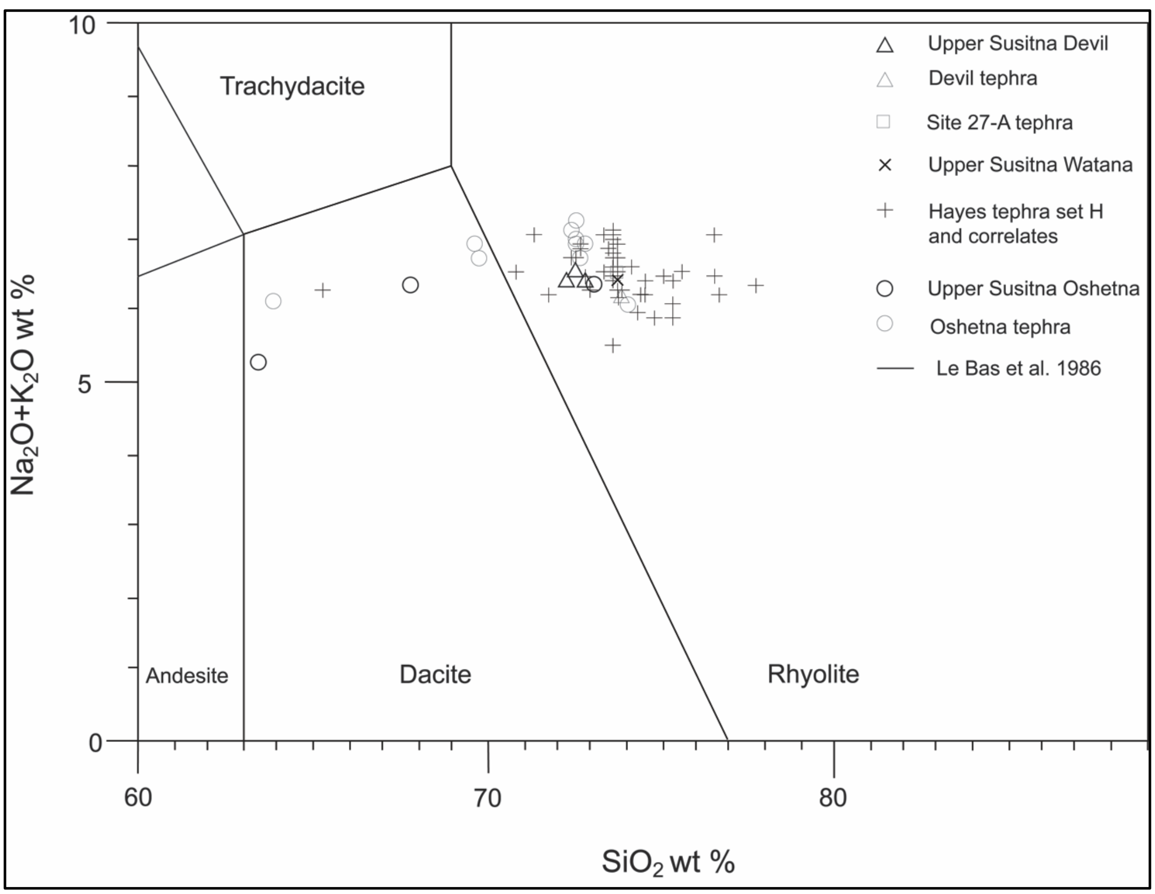

Figure 19. TAS diagram showing mean geochemical classification of upper Susitna tephra samples and previously published tephra geochemistries.

Table 10. Major element glass compositions from the upper Susitna basin.

Sample name	Tephra unit	Lat/Long (NAD83)		SiO_2	TiO_2	Al_2O_3	FeO_T[1]	MnO	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$Total_{raw}$	n
HEA-509-S4[2] (AT-2790)[3]	Devil	63.18788401 -147.54412665	mean	72.79	0.26	14.73	2.13	0.11	0.61	2.58	3.93	2.46	0.41	0.07	92.58	26
			1 σ	*1.48*	*0.07*	*0.51*	*0.4*	*0.03*	*0.18*	*0.4*	*0.35*	*0.26*	*0.1*	*0.05*		
HEA-506-S4[2] (AT-2791)[3]	Devil	63.25122091 -147.50694614	mean	72.32	0.34	14.9	2.35	0.07	0.59	2.63	3.79	2.6	0.38	0.1	94.12	16
			1 σ	*1.31*	*0.11*	*0.36*	*0.44*	*0.02*	*0.13*	*0.29*	*0.3*	*0.08*	*0.14*	*0.05*		
HEA-455-S4[4]	Devil	63.17721939 -147.54222106	mean	72.53	0.1	14.87	2.12	0.24	0.63	2.53	3.71	2.83	0.35	0.1	98.77	16
			1 σ	*1.63*	*0.03*	*0.3*	*0.5*	*0.12*	*0.19*	*0.49*	*0.67*	*0.59*	*0.12*	*0.04*		
HEA-455-S3[4]	Watana	63.17721939 -147.54222106	mean	73.74	0.1	14.57	1.74	0.21	0.5	2.28	3.78	2.64	0.37	0.08	98.11	19
			1 σ	*0.94*	*0.07*	*0.46*	*0.24*	*0.17*	*0.11*	*0.21*	*0.2*	*0.11*	*0.05*	*0.06*		
HEA-455-S2-P1[4]	Oshetna	63.17721939 -147.54222106	mean	73.15	0.73	13.47	3.14	0.08	0.57	2.20	3.33	2.99	0.16	0.17	98.66	10
			1 σ	1.67	0.42	1.07	0.83	0.03	0.25	0.71	0.39	0.90	0.08	0.13		
HEA-455-S2-P2[4]	Oshetna	63.17721939 -147.54222106	mean	67.76	1.07	14.77	5.02	0.15	0.98	3.43	3.55	2.78	0.14	0.35	99.38	5
			1 σ	2.18	0.28	1.50	1.02	0.06	0.37	0.94	0.96	0.66	0.08	0.11		
HEA-455-S2-P3[4]	Oshetna	63.17721939 -147.54222106	mean	63.46	0.96	15.80	6.12	0.15	2.32	5.47	3.70	1.57	0.17	0.29	100.61	3
			1 σ	0.14	0.02	0.12	0.09	0.00	0.16	0.21	0.12	0.06	0.06	0.01		

Watana Tephra Analysis

One subsample of the Watana tephra was analyzed for this research, from sediment sample 3b at Susitna River 3 (HEA-455-S3) (Figure 13). Table 8 provides a physical description of the Watana tephra sample. In the upper Susitna study area, the Watana tephra underlies the Devil tephra, and typically has a heavily weathered upper horizon with a Munsell color of reddish brown, and a weakly weathered lower horizon with Munsell colors ranging from pink to light brown, and a sandy loam field texture. The Watana sample has rhyolite matrix glass containing 73.74 wt % SiO_2 (Figure 19), and uniform glass composition with low standard deviations (Table 10). These characteristics are similar to the Watana tephra described in the middle Susitna basin (Table 2). Radiocarbon dates bracketing the Watana tephra in the upper Susitna study area suggest that it was deposited between 4090 and 2427 cal BP.

Oshetna Tephra Analysis

One subsample of the Oshetna tephra was analyzed for this research, from sediment sample 2 at Susitna River 3 (HEA-455-S2) (Figure 13). Table 9 provides a physical description of the Oshetna tephra, which underlies the Watana tephra and typically overlies glacial drift, occurring as an unoxidized horizon, with Munsell colors ranging from light gray to gray, and a sandy loam field texture. There is commonly a charcoal rich-paleosol developed on the upper portion of the Oshetna tephra, creating a distinct boundary between the

Oshetna and Watana tephras. These characteristics are similar to the Watana tephra described in the middle Susitna basin (Table 2).

The Oshetna sample has variable glass geochemistry; individual glass analyses were plotted on a Total Alkali-Silica (TAS) diagram to distinguish populations (Figure 20). Three glass populations were provisionally identified within the Oshetna tephra, a rhyolite matrix glass population (n=10) with 73.15 wt % SiO_2 and uniform glass composition with relatively low standard deviations; a dacite matrix glass population (n=5) with 67.76 wt % SiO_2 and relatively low standard deviations in all major elements except SiO_2; and a dacite matrix glass population (n=3) with 63.46 wt % SiO_2 and low standard deviations, the result of three analyses from within the same pumice. One point sample with trachydacite glass composition was discarded as an outlier; this sample has an 18.60 wt % Al oxide and may have been affected by a mixed glass/feldspar analysis (Figure 20). Radiocarbon dates bracketing the Oshetna tephra in the upper Susitna study area suggest deposition between 7702 and 5626 cal BP.

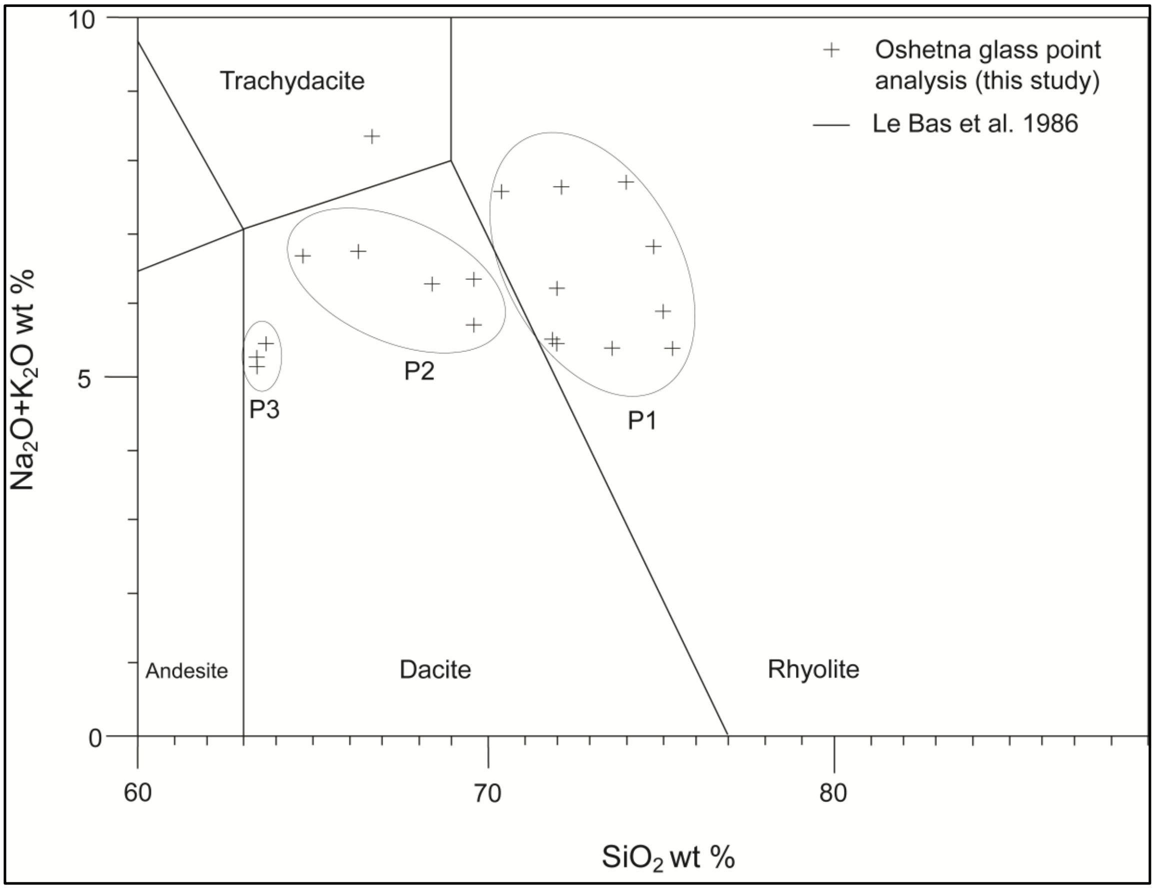

Figure 20. TAS diagram showing individual point glass geochemical classification of upper Susitna Oshetna tephra analyses, grouped into populations.

Discussion

Devil Tephra Correlation

The upper Susitna samples assigned to the Devil tephra have a similarity coefficient (SC) of 0.96 to each other, indicating they represent the same tephra fall (Table 11). Based on SC, stratigraphic position, and physical and geochemical characteristics, these tephra samples represent the same tephra horizon across the study area. Based on field description and stratigraphic position, the upper Susitna Devil tephra correlates with the Devil tephra described in the middle Susitna. A single radiocarbon date underneath the Devil tephra at Susitna River 3 indicates deposition after 2427 cal BP; this is older than dates associated with the Devil tephra in the middle Susitna (approximately 1500-1300 cal BP), but it is a lower limiting date, so it does not preclude correlation.

There is only one set of previously published glass geochemistry data for the Devil tephra from the middle Susitna basin (the Romick Devil sample; Figure 19, Appendix A). The upper Susitna Devil tephra samples are geochemically similar to the middle Susitna sample in that they contain rhyolitic glass (Figure 19); however, they have a SC of 0.90-0.91 with the middle Susitna sample, indicating they could be from the same tephra set, but not necessarily the same tephra fall. This is not as strong of a SC as expected, given the stratigraphic,

Table 11. Geochemical similarity tables showing previously published tephra samples correlated to Upper Susitna study area tephra samples (shown in bold print), using oxides of Si, Al, Fe, Mg, Ca, Na, and K. Minimum SC reported here is 0.90.

Sample	(SC)	Sample	SC	Sample	SC	Sample	SC	Sample	SC
HEA-455-S4		**HEA-509-S4**		**HEA-506-S4**		**HEA-455-S3**		**HEA-455-S2-P1**	
HEA-455-S4	1.00	HEA-509-S4	1.00	HEA-506-S4	1.00	HEA-455-S3	1.00	HEA-455-S2-P1	1.00
HEA-509-S4	0.96	HEA-506-S4	0.96	HEA-509-S4	0.96	TL-8	0.99	Oshetna-P2	0.90
ATC-642-P2	0.96	HEA-455-S4	0.96	HEA-455-S4	0.96	Lower Watana	0.99	23-E1	0.90
HEA-506-S4	0.96	23-D	0.95	AT-2560-P1	0.94	TL-9	0.98		
ACT-1078	0.95	ATC-642-P1	0.95	AT-2565	0.94	ATC-638-P1	0.98		
ACT-004	0.95	ATC-642-P2	0.95	ATC-642-P1	0.94	TL-7	0.98		
ACT-1076	0.95	ACT-1076	0.95	AT-2560-P2	0.94	ATC-641	0.98		
AT-2565	0.95	AT-2565	0.95	23-D	0.93	ATC-639	0.98		
ACT-1082-P1	0.95	ACT-1078	0.95	ATC-642-P2	0.93	ATC-640	0.98	**HEA-455-S2-P2**	
ACT-1073	0.95	ACT-004	0.95	ACT-1076	0.93	ATC-633	0.98	HEA-455-S2-P2	1.00
23-D	0.94	AT-2560-P2	0.94	ACT-1073	0.93	Romick Devil	0.98		
ATC-642-P1	0.94	AT-2560-P1	0.94	Oshetna-P2	0.93	27-A	0.98		
AT-2560-P1	0.94	ACT-1073	0.94	ACT-1078	0.93	ATC-634	0.98		
ACT-4009 (P1?)	0.93	Oshetna-P2	0.94	ACT-004	0.93	TL-3	0.98		
AT-2560-P2	0.93	ACT-1082-P1	0.94	ATC-636	0.93	ATC-636	0.98	**HEA-455-S2-P3**	
ACT-4005	0.93	88-TL-CC	0.94	AT-2558-P3	0.92	ATC-643	0.98	HEA-455-S2-P3	1.00
27-A	0.92	ATC-636	0.93	88-TL-CC	0.92	23-C	0.98	Oshetna-P1	0.92
Oshetna-P2	0.92	AT-2559	0.93	ATC-639	0.92	88-TL-CC	0.97		
Upper Watana	0.92	AT-2558-P3	0.93	Upper Watana	0.92	ATC-637	0.97		
AT-2558-P3	0.92	TL-7	0.93	ACT-1082-P1	0.92	23-G	0.97		
ATC-636	0.92	TL-9	0.93	TL-9	0.92	ATC-642-P1	0.96		
ACT-4004	0.92	Upper Watana	0.93	ATC-633	0.92	23-E1	0.96		
88-TL-CC	0.92	ATC-639	0.93	ATC-641	0.92	ACT-4007	0.96		
23-E1	0.92	ATC-633	0.93	ATC-643	0.92	ACT-4005	0.96		
ATC-639	0.91	ATC-643	0.93	ACT-4009 (P1?)	0.92	ACT-4005b (duplicate)	0.96		
ATC-633	0.91	ATC-637	0.92	ATC-637	0.92	AT-2558-P3	0.96		
TL-9	0.91	TL-3	0.92	TL-3	0.92	23-A	0.96		
HEA-455-S3	0.91	ATC-641	0.92	ACT-4005	0.91	AT-2561	0.95		
ACT-4002	0.91	ATC-640	0.92	AT-2559	0.91	Upper Watana	0.95		

Table 11. (Continued)

Sample	(SC)	Sample	SC	Sample	SC	Sample	SC	Sample	SC
TL-3	0.91	ACT-4009 (P1?)	0.92	HEA-455-S3	0.91	ACT-4006	0.95		
ATC-641	0.91	ACT-4005	0.92	ATC-640	0.91	ATC-638-P2	0.95		
Lower Watana	0.91	ATC-634	0.92	TL-7	0.91	ACT-4008	0.95		
AT-2559	0.91	23-E2	0.92	TL-8	0.91	AT-2560-P2	0.95		
ATC-643	0.91	ATC-638-P1	0.91	ATC-634	0.91	ATC-635	0.94		
ATC-637	0.91	HEA-455-S3	0.91	Lower Watana	0.91	ACT-4003	0.94		
TL-8	0.91	Lower Watana	0.91	27-A	0.91	AT-2565	0.94		
ACT-4005b (duplicate)	0.91	TL-8	0.91	Romick Devil	0.90	ACT-1073	0.94		
TL-7	0.91	ACT-4004	0.91	ACT-4004	0.90	ACT-4004	0.94		
ACT-4008	0.91	ACT-4002	0.91	ACT-4002	0.90	ACT-4002	0.94		
ATC-640	0.91	Romick Devil	0.91	23-E1	0.90	ACT-1076	0.94		
ATC-634	0.90	27-A	0.91	ATC-638-P1	0.90	Oshetna-P2	0.93		
Romick Devil	0.90	AT-2558-P1	0.91	23-E2	0.90	AT-2563-P2	0.93		
ACT-4007	0.90	23-A	0.91	23-C	0.90	ATC-642-P2	0.93		
23-E2	0.90	23-E1	0.90			AT-2564	0.93		
ACT-4006	0.90	ACT-4007	0.90			AT-2567	0.93		
23-C	0.90	ACT-4005b (duplicate)	0.90			ACT-4009 (P1?)	0.92		
ATC-638-P1	0.90	ACT-4008	0.90			ACT-004	0.92		
		23-G	0.90			ACT-1078	0.92		
		ACT-4006	0.90			AT-2560-P1	0.92		
		23-C	0.90			AT-2559	0.92		
						HEA-506-S4	0.91		
						HEA-509-S4	0.91		
						HEA-455-S4	0.91		
						ACT-1082-P1	0.90		
						23-D	0.90		

Key:	Devil correlated	Hayes tephra set H correlated	Oshetna correlated

physical, and radiocarbon data suggesting a correlation between the upper and middle Susitna Devil tephras.

Several researchers have suggested that a late Holocene rhyolitic tephra deposited between 900 and 530 cal BP and documented by Riehle (1985) at a series of sites 1-2 km north to northeast of the Hayes Volcano may correlate to the middle Susitna Devil tephra (Dilley 1988; Wallace et al. 2014). The Devil tephra samples reported here have SCs of 0.91-0.92 to Riehle's sample 27-A, the only glass geochemistry data available from these sites (Table 11). A SC of 0.91-0.92 suggests that these samples could be from the same tephra set, but not necessarily from the same tephra fall. While the radiocarbon data broadly suggest a correlation between these samples, the physical and stratigraphic characteristics of sample 27-A are not well reported, so it is difficult to use additional information to support or refute SC analyses.

Issues correlating the upper Susitna Devil tephras with previously published data may not be related to actual geochemical similarities or differences; instead, dissimilarity may simply be due to poor-quality comparative data. The standard deviations reported for the middle Susitna Devil sample are within acceptable limits, but the number of point analyses is not reported, so it is unknown whether the mean data are an accurate representation of Devil tephra geochemistry. In addition, no analytical conditions were reported, so there may be variability in the data unrelated to actual differences in geochemistry. Similarly, the EPMA analysis used for sample 27-A has been criticized for producing data with high variance (Beget et al. 1991), and analytical conditions and number of point analyses are again unreported. This highlights the need for better-reported Devil and potentially Devil-correlated tephra geochemistry data, to more accurately correlate Devil tephra deposits across southcentral Alaska. Towards this end, the data presented here increase the number of published Devil geochemical analyses from one to four, moving towards developing a better understanding of this underreported tephra. Given the issues with previously published geochemical data, the stratigraphic, physical, and radiocarbon data offer the most reliable support that the upper and middle Susitna Devil tephra horizons likely represent the same late Holocene tephra fall.

The Susitna River 3 and Susitna Dune 5 samples correlate (SC 0.94-0.96) with two rhyolitic glass populations in a single sample of the Cantwell ash (ATC-642-P1, ATC-642-P2), suggesting that they could represent the same tephra fall (Table 11). This is an interesting correlation because the two ATC-642 samples are associated with a radiocarbon date that is younger than the age range for other samples of the Cantwell ash, and Beget et al. (1991) suggest that this sample may actually represent a younger eruption of Hayes. The two populations in ACT-642 are very similar to each other, but were able to be distinguished by SiO_2 and Al_2O_3 wt % content (Beget et al. 1991). While there is some variation in the mean SiO_2 values for the Devil tephra sample reported here (Table 10), the Al_2O_3 wt % content in the samples is similar, suggesting that the same two populations are not present in the Devil tephra samples reported here.

Several of the Devil tephra samples presented here have a strong correlation (SC ≥ 0.94) with proximal HH samples from Hayes Volcano, including AT-2565, AT-2560-P1, AT-2560-P2, and 23-D (Table 11). These correlations are problematic, though, because radiocarbon data indicate the HH was deposited approximately 4200-3700 cal BP, much earlier than the estimated date of Devil deposition at 1500-1300 cal BP. They do, however, indicate that the Devil tephra is likely a Hayes Volcano product. Similarly, several upper Susitna Devil tephra samples have a strong SC with samples of the Oshetna tephra (Table 11), but these correlations do not hold up when field description, stratigraphic position, and radiocarbon data are taken into consideration (see below). These misleading correlations show the difficulty in geochemically distinguishing Hayes Volcano eruptive products that are separated by thousands of years. As suggested by other researchers (Wallace et al. 2014), these data cast doubt on the usefulness of geochemistry alone for distinguishing between Hayes Volcano eruptive products of differing ages. Clearly, more detailed research is needed to securely correlate distal LH tephras with the Hayes Volcano (c.f. Wallace et al. 2014).

Watana Tephra Correlation

Based on field description and stratigraphic position, the upper Susitna Watana tephra sample presented here correlates with the Watana tephra described in the middle Susitna basin; however, radiocarbon dates associated with the Watana tephra in the upper Susitna study area are older than the Watana dates in the middle Susitna basin. The distinction between the upper and lower Watana reported in the middle Susitna basin was based on field weathering characteristics, and probably does not represent a separation of chronologically distinct tephra deposits (Dixon et al. 1985).

The Watana tephra is one of several informal local names (Jarvis Creek ash, Tangle Lakes ash, Cantwell ash) and one formal name (Jarvis Ash Bed) given to distal HH-correlated deposits that have been identified across southcentral Alaska more than 650 km northeast of the Hayes Volcano, thought to have been deposited ~4400-3600 cal BP (Beget et al. 1991; Bowers 1979; Péwé 1975a, 1975b; Reger et al. 1964; Riehle 1994; Wallace et al. 2014). Recent research presented bracketing dates on the Jarvis Ash at the headwaters of the Susitna River indicating deposition between 2245 ± 35 ^{14}C BP (2344-2153 cal BP) and 3040 ± 35 ^{14}C BP (Personius et al. 2010), providing a similar, but somewhat tighter set of dates bracketing deposition of HH distal tephra(s) in the study area. The middle Susitna Watana tephras were correlated to HH deposits at HRO based on mineralogy and geochemistry (Dilley 1988; Riehle et al. 1990; Romick and Thorson 1983), but the radiocarbon dates associated with the Watana set in the middle Susitna suggest deposition ~1000 years later than HH deposits, a discrepancy explained by possible radiocarbon date contamination (Dilley 1988). Despite age correlation issues, the Watana tephras are confidently correlated to HH by several researchers (Dilley 1988; Dixon et al. 1985; Dixon Smith 1990; Riehle et al. 1990), while others suggest that more detailed research is needed to confirm this correlation (Wallace et al. 2014).

A TAS diagram of the upper Susitna Watana tephra, proximal HH deposits, and distal HH-correlated deposits shows that the upper Susitna Watana tephra contains rhyolitic glass similar in composition to the majority of HH and HH correlates (Figure 19). The upper Susitna Watana glass geochemistry correlates strongly (SC ≥ 0.95) with glass geochemistry from 33 previously published analyses; 31 (94%) of these are proximal HH or distal HH-correlated deposits (Table 11).

The upper Susitna Watana tephra has a strong correlation (SC ≥ 0.95) with distal HH-correlated samples of the Tangle Lakes ash, Jarvis Ash Bed, Jarvis Creek ash, Cantwell ash, and the upper and lower Watana tephra from the middle Susitna basin. The upper Susitna Watana tephra has a strong correlation (SC ≥ 0.94) with proximal HH samples 23-C, 23-G, 23-E1, and 23-A from HRP, and AT-2558-P3, AT-2561, AT-2560-P2, and AT-2565 from HRO (Table 11).

AT-2565 is from tephra E at HRO, a thin unit representing a minor eruption that probably did not reach the upper Susitna. AT-2558-P3 is from tephra A at HRO, a thin, discontinuous tephra that is poorly understood, but also probably did not reach the upper Susitna. HRO samples AT-2561 and AT-2560-P2 are from tephra F, the thickest HH deposit at HRO. Wallace et al. (2014) found a close SC correlation between HH tephra F and the Jarvis Creek ash, and suggested that tephra F may represent a significant eruption that deposited tephra across southcentral Alaska. Unweathered Watana deposits in the upper Susitna study area have the same field color as tephra F at HRO (Wallace et al. 2014), suggesting a correlation, but the Watana pumices described in Table 9 are from the upper, weathered portion of the tephra, making correlation with tephra F pumice color presented in Wallace et al. (2014) difficult. Riehle et al. (1990) suggested that HRP samples 23-C, 23-E1, and especially 23-G may comprise distal HH correlated tephras in southcentral Alaska.

These analyses highlight the difficulty in using geochemistry alone to correlate distal Hayes eruptive products with specific proximal Hayes tephra beds. Despite these issues, this analysis indicates that the Watana tephra in the upper Susitna basin strongly correlates to HH deposits, both proximal and distal, supporting stratigraphic, physical, and chronological data. Radiocarbon dates associated with the upper Susitna Watana tephra are within the range of dates established for all HH proximal and distal tephras, except for the middle Susitna Watana. This suggests that the dates associated with the Watana tephra in the middle Susitna do not accurately represent the age of Watana deposition in the region.

The middle Susitna Devil sample and sample 27-A also have a high SC with the upper Susitna Watana sample. These samples have been correlated to the Hayes Volcano (Dilley 1988; Riehle 1985), but issues with geochemical data from these two samples are discussed above, and may not be meaningful. As with the Devil tephra, we do not know much about the geochemistry of the Watana tephra in the middle Susitna; only two samples have been reported, and they lack information on analytical conditions and number of point analyses. This research adds another geochemical profile to use as a comparison, but one that is better reported.

Oshetna Tephra Correlation

Based on field description, stratigraphic position, and associated radiocarbon dates, the upper Susitna Oshetna tephra sample presented here correlates with the Oshetna tephra described in the middle Susitna. A TAS diagram shows that the upper Susitna Oshetna populations broadly correlate with previously published Oshetna glass data, in that there are two dacitic glass populations and a rhyolitic glass population (Figure 19). Radiocarbon dates for the upper Susitna Oshetna provide a broad age-range bracketing deposition, but they fall within the range of the Oshetna tephra established in the middle Susitna basin, as well as with the best-documented sampling location for the Oshetna tephra at

Wonder Lake in the central Alaska Range, where tight bracketing dates indicate deposition between 6870-6660 cal BP (Child et al. 1998).

SC comparison of Oshetna samples is problematic though – none of the upper Susitna Oshetna populations defined here have a strong SC correlation to previously published Oshetna data (Table 11). This could be because the provisional Oshetna populations presented here consist of a small number of analyses, and may not represent accurate mean geochemistry for Oshetna glass populations. The Oshetna sample mounted for this analysis was glass-poor, and it was difficult to locate enough glass to get a significant number of point analyses, especially given the apparent heterogeneity in the sample. For tephra deposits with heterogeneous glass shard populations, it is sometimes necessary to analyze as many as ~50 individual glass shards in a sample (Lowe 2011).

Despite the ambiguous attempt to correlate the Oshetna tephra with previously published data, there are some interesting results from this analysis. Previous research highlighted the heterogeneity in the Oshetna tephra. Dilley (1988) presents a dacitic and rhyolitic population in the middle Susitna Oshetna tephra, and Personius et al. (2010) present a dacitic and rhyolitic population in a sample of the Oshetna from the headwaters of the Susitna River; importantly, their rhyolitic population is distinct from the overlying Jarvis Creek ash geochemistry. The upper Susitna Oshetna data support multiple populations in the Oshetna tephra, and suggest as many as three glass populations.

Oshetna heterogeneity has been explained by possible mixing of different tephra units, magma differentiation prior to eruption, or the result of two separate tephra falls that appear as one in the field (Dilley 1988). The distinction between rhyolitic Oshetna and Jarvis populations in Personius et al. (2010) does not support mixing. Distinct Oshetna glass populations may be the result of two tephra falls; evidence from the Susitna dune indicates that there are two tephra horizons underlying the Watana tephra, both with field characteristics of the Oshetna tephra described in the middle Susitna. In addition, at Susitna River 3, a dark stringer of organic material was ephemerally expressed in the lower portion of the Oshetna tephra, possibly indicating soil development in between deposition of what otherwise appears to be a single tephra unit in the field. These data suggest there may be a fourth, as-yet unidentified tephra in the study area, deposited sometime before 7702 cal BP, and commonly mixed in with overlying Oshena tephra deposits in most profiles.

Tephra reworking can typically be identified by the presence of non-volcanic sediment mixed with tephra (Gatti et al. 2012). The upper Susitna Oshetna tephra tends to have sandy sediment mixed into it; similarly, the middle Susitna Oshetna tephra is reported to have sandy sediment mixed into it (Dilley 1988). Oshetna reworking was most pronounced at Susitna Dune 1, where the Oshetna tephra unit contained platy and sub-round clasts <1 mm. This may explain the difficulty distinguishing individual tephra beds within the Oshetna in a field stratigraphic profile.

The possible presence of multiple tephra horizons within the Oshetna tephra at some locations in the upper Susitna basin is interesting when taken in light of the six tephra horizons observed in a peat core collected from a small kettle pond located near the mouth of Watana Creek in the middle Susitna valley (Dilley 1988; Dixon and Smith 1990). The evidence for multiple tephras within the “Oshetna” tephra lends some support to Dixon and Smith’s (1990) interpretation that the lower three tephra horizons identified in the core (D, E, and Oshetna) may be mixed into the Oshetna tephra in terrestrial settings, although this study only found evidence for two tephras mixed into the Oshetna. There is also evidence for a reworked tephra horizon underlying a tephra provisionally identified as the Oshetna at two sites in the lowlands of the Susitna basin (Wygal and Goebel 2012), providing additional support for a regional sub-Oshetna tephra.

Future analysis needs to focus on better delineating glass populations in the Oshetna tephra through larger numbers of glass point analyses. EPMA and micromorphological analysis of the pre-7702 cal BP tephra on the Susitna dune is forthcoming. These analyses are important if we are to use the Oshetna tephra as an accurate tephrochronological marker. To better understand the distal Oshetna tephra, we need to find a proximal sampling location that can shed light on the apparent variability in this tephra deposit. Wallace et al. (2014) describe a possible Oshetna-related rhyodacite flowage deposit at HRO, but no glass geochemistry data is currently available for comparison to distal Oshetna glass.

Tephra Summary. Volcanism has significantly influenced the landscape in the upper Susitna basin. This study contributes to our understanding of underreported Susitna basin tephra geochemistry, using contemporary microprobe analyses, geochemical standards, and laboratory techniques. The analysis presented here uses stratigraphic, physical, radiocarbon, and geochemical data to more securely correlate upper Susitna tephras with regional proximal and distal tephra horizons.

The Hayes Volcano produces distinct, high-silica rhyolitic eruptive products in comparison to other Cook Inlet volcanoes (Wallace 2003; Wallace et al. 2014). The data presented here indicate that the Devil and Watana tephras are high-silica rhyolitic tephras, and are likely products of the Hayes Volcano. The Oshetna tephra has a high-silica rhyolitic population, but also has dacitic populations. This may not preclude it from association with the Hayes Volcano; recent research indicates that the Hayes Volcano produced also dacitic, rhyodacitic, and rhyolitic magmas in the past (Wallace et al. 2014).

Moving forward, the correlations presented here could be strengthened with petrographic analyses, as Hayes Volcano eruptive products are mineralogically distinct from other volcanoes in southcentral Alaska (Riehle 1985; Wallace et al. 2014). In addition, Fe-Ti oxide geochemistry analysis has shown promise for distinguishing individual HH beds (Wallace et al. 2014).

Developing a better understanding of HH deposits is important to Holocene archaeological studies in Alaska because of their widespread regional occurrence. It is still unclear how many tephra ejections comprise the HH at proximal locations, and how many of these tephra ejections were widely dispersed across southcentral Alaska (Riehle et al. 1990; Wallace et al. 2014).

Landscape History of the Upper Susitna River Basin

The upper Susitna basin was significantly affected by a series of glacial advances and retractions until the last major phase of late Wisconsin glaciation began to retreat ~14,000-13,000 cal BP. This coincides with regional evidence for the end of full-glacial conditions ~12,000 cal BP. This study presents OSL data suggesting that the Susitna dune began to form as early as 16,865 ± 1010 cal BP. This date is earlier than expected; the glacial drift underlying the Susitna dune is thought to have been deposited during the last significant phase of glaciation of the study area (Smith et al. 1988; Woodward Clyde 1982), most recently dated to 14,000-13,000 cal BP (Dortch et al 2010). It could be that the glacial drift upon which the Susitna dune formed on was instead deposited during the significant period of glacial ice recession recognized regionally after 19,000 or 16,000 cal BP, and that dune formation began after this, or the OSL date may simply be erroneous. The Susitna dune OSL date presented here could indicate that the last significant pulse of glaciation did not cover as much of the study area as previously suggested, but this needs to be further investigated with additional cosmogenic and OSL dating throughout the study area.

Following deglaciation, there is evidence for a period of high-energy aeolian activity in the study area represented by formation of the Susitna dune. No other dunes as large as the Susitna dune were observed in the study area, although lower-elevation landforms in the vicinity of the dune were often blanketed with thin sand deposits. A geomorphological survey north of the Susitna dune on Monahan Flat indicated that most of the minor topographic landforms in this area are glacial outwash formations, and do not have significant sediment accumulation on them. This suggests that post-glacial dune building was localized, constrained to specific topographic settings, but this needs to be confirmed with additional geomorphological survey of the study area.

At most archaeological test locations in the study area, there is no evidence for significant geomorphological change following post-glacial deposition of the glacial drift deposits. Charcoal collected from the Susitna dune suggests woody vegetation appeared by 12,220 cal BP. Charcoal associated with a Cervid mandible at Susitna Dune 1 suggests faunal resources were available by 10,970 cal BP. Several sites in the study area have weathering profiles on glacial drift, but only at Susitna River 3 is this clearly related to A horizon development on drift deposits, indicating landscape stability and vegetation growth following deglaciation. *Salix* charcoal collected from this paleosol suggests woody vegetation at Susitna River 3 by 10,520 cal BP. This coincides with basal peat dates of 9035 ± 335 ^{14}C B.P (11,173-9469 cal BP) and 9195 ± 150 ^{14}C BP (11,054-9914 cal BP) from nearby Boulder Creek and Snodgrass Lake, respectively (Figure 10), indicating the development of peat deposits in the study area by this time (Reger and Bundtzen 1990), although basal peat deposits radiocarbon dated for this study indicate that peat in the upper Susitna basin may not be this old (see Chapter II).

The post-glacial depositional sequence consists primarily of tephra fall, with minor or localized aeolian sediment deposition. There is no evidence for alluvial- or fluvial-deposited sediments at any archaeological sites tested for this research, and only minor evidence for colluvial deposition in specific situations (e.g., Butte Creek 1). There is preliminary evidence for a minor MH tephra fall prior to deposition of the Oshetna tephra, but this is poorly understood with the current level of data. The A/Eb2 horizon capping this tephra horizon on the Susitna dune marks a period of dune stability, vegetation growth, and soil formation at 7788-7627 cal BP. Following this, there is evidence for a period of dune mobilization, recorded by aeolian sand deposits overlying the A/Eb2 at multiple locations on the dune, then deposition of the Oshetna tephra. This sequence may be a regional signal; research in the middle Susitna basin described a sub-Oshetna paleosol associated with radiocarbon dates of 7240 ± 110 ^{14}C BP (8324-7855 cal BP) and 6970 ± 210 ^{14}C BP (8199-7436 cal BP), sometimes associated with cultural material; in many locations this paleosol was capped with aeolian sediment deposits (Dixon et al. 1985:I; Dixon and Smith 1990). These ages broadly correlate with the period of dune stability approximately 7700 cal B.P in the upper Susitna basin.

Lacustrine cores from Swampbuggy and Nutella lakes (Figure 10) suggest lake formation just prior to 6750 ± 130 ^{14}C BP (7919-7423 cal BP); at this time vegetation in the study area consisted of xeric/mesic shrub heath tundra to open forest-tundra, with scattered spruce (Rohr 2001). These data suggest a regional period of stabilization and human occupation ~8000-7600 cal BP, followed by a period of instability/erosion and aeolian deposition, evidenced by re-activation of the Susitna dune.

The next event to significantly affect the upper Susitna study area was deposition of the Oshetna tephra. The Susitna dune appears to have been actively building until just after deposition of the Oshetna tephra. A radiocarbon date from bedded dune deposits representing active dune building 11,170-10,770 cal BP, and the absence of unequivocal pedogenic horizons representing dune stability and soil formation in pre-Oshetna dune deposits support this.

Across the study area, the Oshetna tephra is capped by a charcoal-rich paleosol. Dates associated with this paleosol range from 5626-4089 cal BP and represent a period of landscape stability and soil formation. Charcoal samples from the Oshetna paleosol were identified as *Picea*, *Salix*, and *Betula* (Table 4), suggesting that these woody species were present at this time. The Oshetna tephra typically has the appearance in the field of a leached albic E horizon with a thin, charcoal-rich A horizon formed on the uppermost portion of the unit, and underlying sediments typically have illuviated materials. Dense charcoal associated with the Oshetna paleosol could be the result of human activity at archaeological sites, but the charcoal horizon typically has the appearance of *in situ* vegetation burn, and is present across the Susitna dune with no associated cultural material. This could indicate a significant fire, or series of fires, affected the study area during the MH. Research in the middle Susitna basin identified two spikes in charcoal production, one ~4770 cal BP and one ~3420 cal BP, possibly associated with regional paleoenvironmental events. For example, previous research tied increased forest fires in southcentral Alaska to cooler, wetter conditions in the MH, the result of a combination of increased ignition by lightning strikes and seasonal-moisture variability (Lynch et al. 2004). Data from the upper Susitna study area adds support to regional fire regime change in the MH; however, Neoglacial cooling in Alaska is typically marked by increased sediment deposition (Mason and Beget 1991), and there is no evidence for increased sediment deposition in between deposition of the Oshetna and Watana tephras.

Sometime between 4089 and 2472 cal BP the Watana tephra was deposited in the upper Susitna basin. The Watana tephra is consistently the thickest tephra deposit in the study area, and is typically heavily weathered into a distinct reddish-brown B horizon, often with a lower, less weathered, light brown BC horizon. On the Susitna dune, the upper portion of the Watana tephra is typically weakly cemented into pebble-sized concretions. LOI analysis indicates that the Watana tephra typically shows an increase in percent OC from the overlying E horizon. An increase in percent OC could represent illuviated colloidal organic matter causing a secondary peak of OC in the B horizon, and cementation could represent illuviation aluminum and iron compounds to form a placic horizon, both characteristics of a spodic B horizon in a Spodosol (Schaetzl and Anderson 2005; Soil Survey Staff 1999). Most lithic artifacts recovered from subsurface contexts in the study area are stained brownish-black on one or more sides, offering additional support to the influence of intensely illuviated materials in the soil profile.

Spodosols typically have a sequence of an organic A horizon, albic E horizon, and underlying Bhs or Bs horizons. In some Spodosols, an argillic horizon forms below the spodic horizon (Soil Survey Staff 1999); the Bt horizon identified on the Susitna dune could be related to Spodosol development. Spodosols typically form in cool, moist climate regimes like that of the upper Susitna basin (Soil Survey Staff 1999). Spodosols are well documented elsewhere in southcentral Alaska, including the middle Susitna basin (Dilley 1988; Ping et al. 1989). These characteristics are similar to the modern soil profile in the study area, however soil taxonomy needs to be further explored with laboratory analyses to confirm classification.

Research in the middle Susitna basin found evidence for multiple tephra falls comprising the Watana tephra, sometimes separated by incipient soil development and associated cultural material (Dixon et al. 1985:I). There are three closely-spaced tephras in a lacustrine core collected from Swampbuggy Lake, bracketed by dates of 4869 ± 40 ^{14}C BP (5710-5482 cal BP) and 3370 ± 45 ^{14}C BP (3716-3479 cal BP) (Rohr 2001). The uppermost of these tephra units was identified as the Jarvis Ash, but, given the associated dates, it is likely that all three are related to Hayes tephra set H, providing additional evidence for multiple tephra falls comprising the Watana tephra in the study area. This study did not find evidence of multiple Watana units in the upper Susitna, but the heavy weathering profile associated with spodic B horizon development may have masked bedding characteristics or incipient A horizons within the Watana tephra. Further laboratory analysis is necessary to determine if this is the case (Ito et al. 1991; McDaniel et al. 1997).

The Devil tephra is the final tephra fall to affect the study area, deposited sometime after 2427 cal BP. There is no evidence of significant sediment deposition or soil formation in-between the Watana and Devil tephras, but soil formation may have been masked by formation of spodic horizons as described above. An alternative explanation is that deposition of the Watana tephra significantly disrupted vegetation and overall productivity, resulting in little soil development in the time between deposition of the Watana and Devil tephras. Palynological research did find evidence for lower pollen concentration values associated with possible tephra deposits suggesting less vegetation (see

Chapter II), but vegetation response to tephra fall needs to be explored with additional research.

The Devil tephra has the appearance in the field of a leached, albic E horizon overlying the oxidized B horizon of the Watana tephra. At most sites, the upper portion of the Devil tephra contains organic matter, apparently the result of A horizon development on tephra sediments following deposition. However, there is consistently a significant decrease in percent OC in the Devil tephra. Because of these characteristics, the Devil tephra was assigned an EA soil horizon designation. Researchers have pointed out the difficulty in separating an albic E horizon from a C horizon with an incipient A horizon in tephra-derived soils (Ito et al. 1991; McDaniel et al. 1997), but the presence of a spodic B horizon underlying the Devil tephra suggests that it represents an E horizon.

During the period when the Watana and Devil tephras were deposited, the Susitna dune appears to have been stable; however, there is evidence that aeolian processes responsible for dune building may have resulted in thicker Devil tephra deposits on the dune. Also, the Watana and Devil tephras in the Susitna dune typically have a sandy loam texture, whereas elsewhere in the study area they have a silt loam texture, suggesting some post-depositional mixing or reworking. While it is difficult to make substantial assertions about the effects of climate change on local geomorphology from the depositional history of a single dune, there are some interesting aspects of Susitna dune formation that could potentially relate to shifting climate, as aeolian-derived landscape features can aid in reconstructing local and regional scale paleoenvironmental conditions (Seppälä 2004).

LP/EH aeolian activity outcompeting vegetation growth on the dune could represent sparse vegetation and exposed sediment sources in the study area (c.f. Bigelow et al. 1990; Dilley 1998). Stabilization of the Susitna dune in the middle Holocene could be related to increasing spruce density and emergence of dense forest tundra reported for the study area approximately 5700 cal BP (Rohr 2001). Vegetation change could have stabilized the dune, as well as stabilized sediment sources supplying the dune. A similar pattern of LP/EH aeolian aggradation followed by middle Holocene dune stabilization has been recognized in the Tanana Valley and throughout the broader central Alaska region, and it is thought to relate to warming temperatures, an increase in effective moisture, and resulting spread of conifers (Bigelow 1997; Reuther 2013).

In most testing locations, there is a minor amount of aeolian silt deposited on top of the Devil tephra, upon which the modern A horizon has developed. The addition of aeolian silt may have halted A horizon development directly on the Devil tephra, and caused a cumulative A horizon to develop. The aeolian sediment source for this silt is probably fluvial silt deposits from the braided Susitna River, which are present in the study area today. However, there is no consistent modern accumulation of silt in the study area (e.g., silt deposited on an O horizon or on erosional surfaces). The development on an incipient A horizon on the Devil tephra and lack of evidence for modern silt accumulation suggest a period of increased aeolian sedimentation in-between deposition of the Devil tephra and modern times, possibly related to cooling and during the Little Ice Age.

The Susitna dune has been affected by recent erosional activity creating blowouts along the southern edge of the dune, and there are what appear to be somewhat older blowouts that have been re-vegetated in recent years. More recent blowouts on the southern side of the dune suggest a shift in predominant wind regime to winds coming from the south, but this may just represent seasonal shifts in wind direction (Shulski and Wendler 2007).

Correlating landscape change and soil development in alpine settings (roughly >1000 masl) with lower elevations is problematic. We only tested one site in an alpine setting, Alpine Creek 8 in the Clearwater Mountains, and the profile at this site was significantly different than those of all other sites we tested. The most obvious difference is that the distinct tephra horizons observed in lower elevations were not present at Alpine Creek 8. However, tephra pumice is mixed into lower strata at the site, suggesting that one or more of the tephra falls that blanketed lower elevations of the study area were also deposited in alpine settings. As described above, it is possible that outwash, alluvial, or fluvial action correlated with Holocene expansion and retraction of alpine glaciers significantly reworked tephra and other sediments at Alpine Creek 8, but this needs to be explored further with additional testing in alpine settings.

There is little evidence at the sites presented here for significant geomorphic change associated with Neoglaciation (~4000-2000 cal BP) or the Little Ice Age (~770-70 cal BP) (Barclay et al. 2009). Elsewhere in the study area, Rohr (2001) correlated the spread of spruce forest tundra in lower elevations to cooler, moister conditions of the Neoglacial period. At the confluence of Raft Creek and the Susitna River, a spruce log collected from a peat bed directly overlying a tephra horizon at the base of an 11-m section of sand and gravel yielded a standard radiocarbon date of 2030 ± 400 ^{14}C BP (3005-1181 cal BP) (Rubin and Alexander 1960:166). Similarly, a log collected from within a 5-m terrace of alluvial sand, silt, and gravel on the west bank of the Susitna River near its confluence with Clearwater Creek yielded a radiocarbon date of 2000 ± 200 ^{14}C BP (2486-1422 cal BP) (Rubin and Alexander 1960:166). These dates were interpreted by the original investigators to mark the beginning of a period of strong alluviation of the Susitna River and tributaries following deposition of what is likely the Watana tephra, possibly related to glacial advance in nearby mountains (Rubin and Alexander 1960:166).

Mason and Beget (1991) report an interval of large floods in the Tanana basin between ~3200-2000 cal BP, the result of increased storminess and higher precipitation tied to climate change associated with Neoglacial cooling. Given the data presented here, it appears that Neoglacial cooling may have brought geomorphic change in the study area, possibly from changing weather patterns, but this change may have been relegated to lower elevations in the

Susitna basin, and did not affect sites tested for this study. This research presents an emerging picture of landscape change in the upper Susitna River basin. In the following section, I return to research questions related to human occupation of the study area to assess how landscape change may have affected human use of the study area.

When did humans first occupy the upper Susitna study area, and what was the geomorphic context of initial occupation?

Based on the evidence presented here, humans first occupied the upper Susitna River basin in the EH, possibly as early as 10,970 to 10,520 cal BP (Figure 21), some 3000 years after the end of full glacial conditions in the study area, and ~1000 years after minor glacial re-advances during the Younger Dryas. There is currently very little paleoecological information with which to understand post-glacial landscape recovery, or the environmental context of initial human use of the study area. Regionally, hunters occupied Bull River II at 12,500 cal BP, possibly 1500 years after deglaciation (Wygal 2010).

Recent research in western Canada indicates that a viable, productive landscape capable of supporting grazing faunal populations emerged shortly after recession of the Laurentide and Cordilleran ice sheets in the ice-free corridor (Ives et al. 2014). These data can be used as an analogue for the study area, suggesting that post-glacial landscape recovery may not have been an important barrier to human occupation; however, Dixon et al. (1985:I:8-55) hypothesized that stagnant ice and large areas of unstable ground may have persisted for several thousand years following deglaciation, and could have hindered initial human occupation.

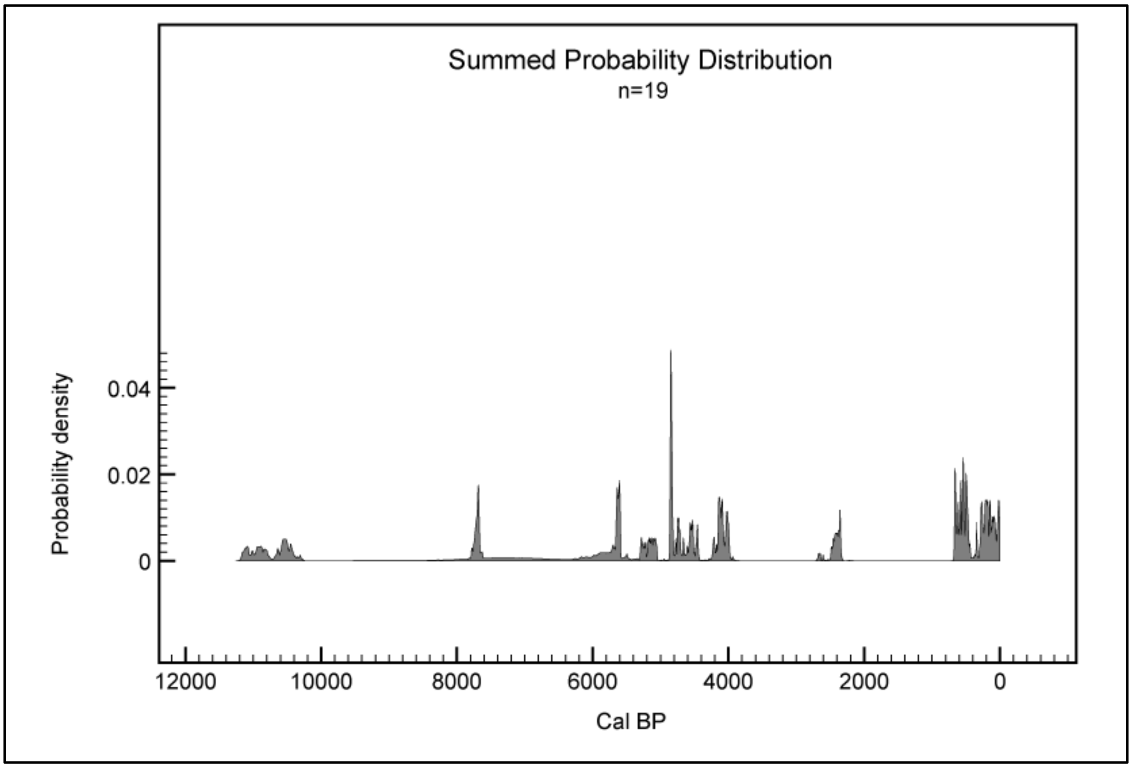

Figure 21. Summed probability distribution of radiocarbon-dated sites in the upper Susitna study area (calibrations from OxCal v4.2.4). See Figure 22 for information on radiocarbon dates included here.

Initial human use of the study area appears to coincide with paleosol formation on glacial drift and regolith sediments, suggesting a period of landscape stability and vegetation growth, but this was also a time of dune building on the Susitna dune, suggesting that portions of the landscape were still geomorphologically active. Charcoal wood identifications indicate that woody plants, including willow, were available as a fuel source at this time. Humans moved south through the Alaska Range and were present in the broader region prior to the first evidence of humans in the study area, including at Eroadaway, Bull River II, and Carlo Creek to the west; Jay Creek Ridge to the south; and the Tangle Lakes sites of Phipps, Whitmore Ridge, and Sparks Point to the east (Bowers and Reuther 2008; Dixon et al. 1985; Dixon 1993; Holmes et al. 2010; West et al. 1996a, 1996b, 1996c; Wygal 2009, 2010). The perceived delay in human occupation of the upper Susitna basin needs to be further explored from an ecological and landscape recovery perspective. Continued research focused in the study area may lead to the discovery of earlier sites rivaling the age of uplands sites in the surrounding region.

What is the sequence of archaeological site occupation through the Holocene?

The EH archaeological record for the study area is sparse (Figure 21). This study found evidence for EH occupation at two sites, Susitna Dune 1 (C1) (11,170-10,770 cal BP) and Susitna River 3 (C1) (10,690-10,300 cal BP). Cultural material at Susitna Dune 1 appears to reflect a short-term camp or activity site, while the record at Susitna River 3 suggests more intensive activity and likely represents a resource extraction camp. The archaeological record suggests initial forays into the study area in the earliest Holocene, as early as 10,520 cal BP. The record at Butte Lake (HEA-189) appears to support this inference; researchers here recovered a small lithic assemblage that, while undated, is thought to represent an ephemeral EH occupation of the site (Betts 1987; Wendt 2013).

The MH archaeological record for the study area is significantly more substantial than the EH record in terms of number of sites and site density (Figures 21 and 22). This study found evidence for MH occupation at five sites, Susitna Dune 1 (C2), Susitna Dune 4 (C2), Susitna River 3 (C2), Butte Creek 1 (C1), and West Fork Susitna 1 (C1). Radiocarbon dates associated with these components span a period of 7788-4089 cal BP. There is evidence from the Susitna dune for ephemeral human activity in the early MH at 7700 cal BP, associated with a regional period of landscape stabilization and human occupation of the greater Susitna basin ~8000-7600 cal BP. The early MH sites appear to represent use of the study area by small groups operating out of short-term hunting camps.

Lithic assemblages from Susitna River 3 (C2) (LAD 171.7/50 cm^2) and Butte Creek 1 (C1) (LAD 192.3/50 cm^2) represent the highest artifact density of any components in the study area. These also have the densest faunal remains in the study area. Susitna River 3 (C2) represents an intensive Northern Archaic occupation of the study area. Given the density of cultural material and dense feature in this context, C2 may represent a residence or aggregate hunting camp. At Butte Creek 1, artifact density and two significant cultural features indicate intensive use of the site. Radiocarbon dates associated with these features span a period of about 200 years, suggesting this location was revisited during the MH, which may explain high artifact and feature density. The dense burned-bone Feature 2 suggests the site was used as an intensive subsistence processing location, focused on processing caribou bones for grease and marrow, or simply disposing of a large amount of bone in a fire (see Workman 1976). This supports previous research in the middle Susitna basin that found MH hunters in the Talkeetna Mountains focused subsistence activities on hunting caribou, and commonly disposed of bones in hearth fires (Skeete 2008). The lithic assemblage from West Fork Susitna 1 is sparse, and probably represents a short-term hunting camp or activity site, possibly logistical resource extraction camp (Binford 1980; Kelly 1995).

The MH archaeological record appears to indicate intensification of subsistence activities in the study area during the MH period, by larger groups, or for longer durations, especially between 4848-4089 cal BP. The MH record at Butte Lake shows increased artifact density and the presence of cultural features representing longer term or continual use over time (Betts 1987; Wendt 2013). Dense surface artifact assemblages from the Ratekin site (including notched Northern Archaic points) have been interpreted to represent an MH occupation; this is supported by a radiocarbon date of 3745 ± 50 ^{14}C BP (4248-3929 cal BP [AA-19324; *Salix* wood charcoal; $\delta^{13}C$=-25.5 ‰]) from a hearth feature at nearby HEA-320 indicating human use of the landform in the MH (C. Holmes personal communication 2013), but there is ethnographic evidence for use of the site into historic times, so the surface assemblage should be considered a palimpsest.

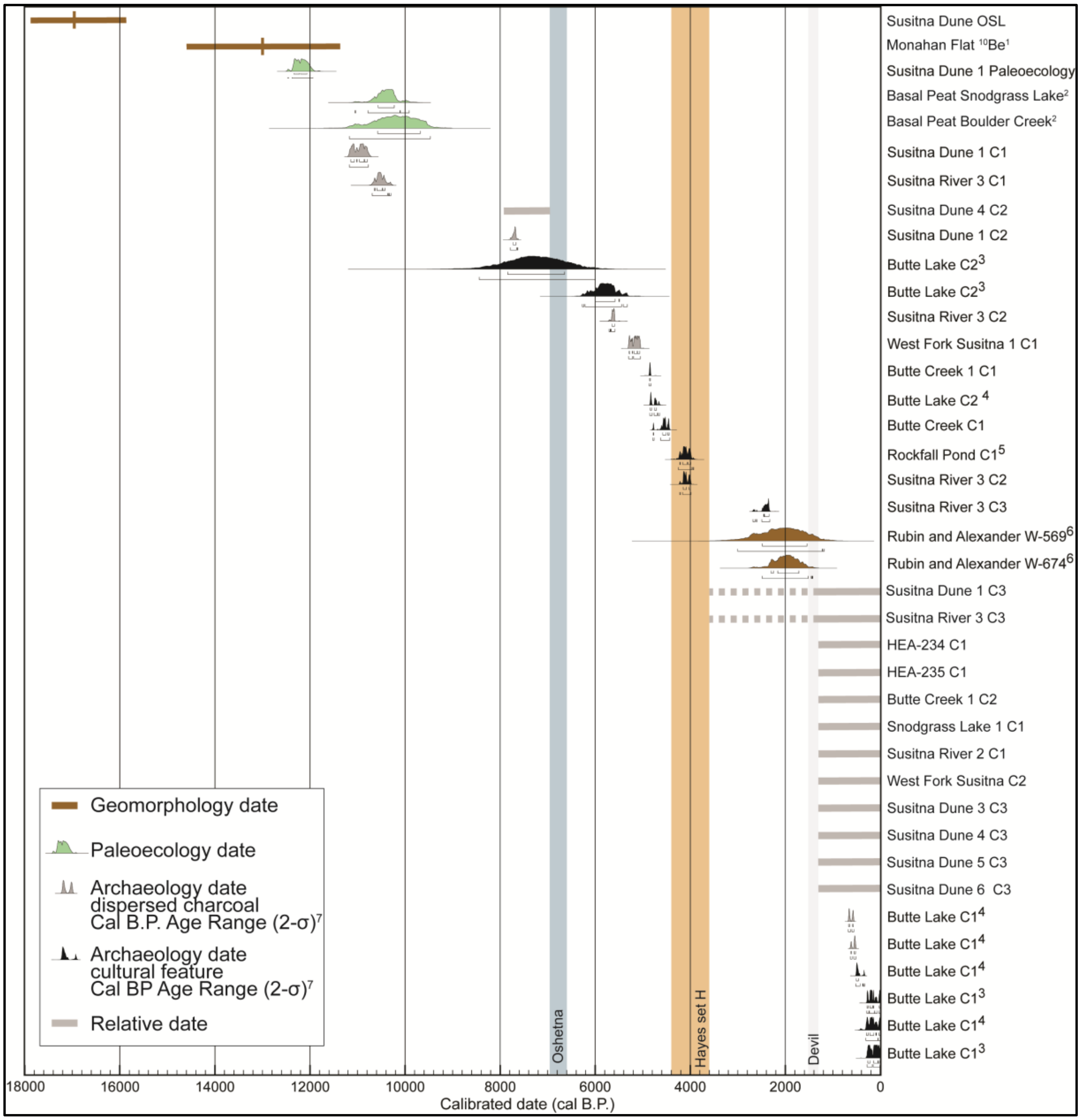

Figure 22. Upper Susitna timeline of events ([1]Dortch et al. 2010, [2]Reger and Bundtzen 1990, [3]Betts 1987, [4]Wendt 2013, [5]C. Holmes personal communication 2013, [6]Rubin and Alexander 1960, [7]Reimer et al. 2013).

The LH archaeological record for the study area shows an increase in the number of sites, but a decrease in density of lithic artifacts per site (Figures 21 and 22). This study found evidence for LH occupation at 14 sites (HEA-454, 507, 508, 509, 510, 511, 234, 235, 455, 460, 499, 502, 506, and 500). The densest site with an LH lithic assemblage is Alpine Creek 8 (LAD 130.6/50 cm^2), an alpine quarry camp. At lower elevations, Susitna Dune 1 has moderate artifact density (LAD 13.1/50 cm^2) and a shallow hearth feature, and Butte Creek 1 (LAD 12.5/50 cm^2) has moderate lithic artifact density, both sites representing short-term campsites. Only the LH occupation at Susitna River 3 has any indication of appreciable lithic artifact density (LAD 72.8/50 cm^2), but still lower than MH sites and probably represents a short-term camp. The rest of the 10 sites with LH assemblages appear to represent procurement/special task sites.

The LH archaeological record represents continued use of the study area, but with less artifact density and different types of cultural features than in the MH. There is also a shift in the location of sites to diverse topographic locations (e.g., major and minor promontories, alpine, dune). These attributes of site location and structure use indicate a shift in landscape use between the MH and LH. An example of this is at Butte Creek 1 (HEA-499), where we found evidence of intensive MH bone processing, but we found no evidence of site use prior to this in the EH, and only ephemeral activity in the LH. At Butte Lake, there is evidence for a significant LH occupation, with a residential depression feature and intensive caribou bone-processing features (Betts 1987; Wendt 2013). It may be that subsistence activities in the LH included forays out of lakeside camps like Butte Lake (as predicted in Potter 2008), instead of high overlook camps like Susitna River 3. The less dense LH sites presented here could represent small family groups using encounter-hunting techniques, contrasting with larger groups cooperating on intercept hunts during the MH (e.g., Rasic 2011).

How did landscape change and tephra fall affect human use of the uplands? The geomorphic data from the upper Susitna basin study area suggest relative geomorphic stability following glaciation. The regional paleoecological record suggests that vegetation below 700 masl in the study area may have been shifting from *Betula* shrub tundra to first *Populus* and then *Picea* open woodland during initial occupation. The study area was sparsely occupied during MH tephra deposition, represented by the possible unnamed tephra at Susitna dune, and the Oshetna tephra present throughout the study area. There is sparse archaeological material associated with a paleosol formed on the unnamed tephra, suggesting human use of the study area shortly after deposition. Given the relative thinness of this tephra deposit, it may not have significantly affected the study area. The age range for deposition of the Oshetna tephra in the study area is broad; it is more realistic to use the tighter age presented in Child et al. (1998).

The oldest component following deposition of the Oshetna tephra is at Butte Lake, where C2 is dated to 5030 ± 200 ^{14}C BP (6272-5325 cal BP) (Wendt 2013), and at Susitna River 3, where C2 is dated to 5711-5585 cal BP. These dates indicate a possible hiatus following deposition of the Oshetna tephra, but again this is difficult to discern because human use of the study area was apparently so sparse during this period anyway. Within about 1000 years of Oshetna deposition, there appears to be no remaining effects, as the densest archaeological sites date to between 4848-4089 cal BP (Figure 22), around the beginning of the Neoglacial period.

There appears to be somewhat of a hiatus in the study area following deposition of the Watana tephra, the most significant tephra fall in the study area that appears to correlate with the Hayes set H recognized regionally (Figure 22). Only one site, Susitna River C3, has definitive evidence for occupation within 2000 years after the Watana deposition. This could be related to ecological disturbance following Watana deposition, or to widespread cooling and environmental degradation associated with Neoglaciation as discussed above, or it could be an artifact of a relatively small sample size of radiocarbon-dated sites. There is no apparent hiatus in occupation following deposition of the Devil tephra, and again given the thinness of this deposit, this may be due to the relatively small volume and minor environmental impact of this tephra fall. The same pattern is reported at Butte Lake, where Wendt (2013) describes a hiatus

3500-1500 cal BP, possibly attributed to Watana tephra deposition, but more likely attributed to declining conditions associated with Neoglaciation.

In the middle Susitna valley, researchers found no evidence for any discontinuities in the Holocene archaeological record following tephra fall (Dilley 1988). Contrasting this, research in the lowlands of the Susitna basin west of the Talkeetna Mountains found evidence of site occupation through the EH and MH, but apparent site abandonment following deposition of the Hayes tephra (Wygal and Goebel 2012). The middle Susitna research represents a larger research project, and the patterns presented here from the upper Susitna may be the result of smaller sample sizes. Also, it is necessary to carefully consider whether changes in the archaeological record are related to regional ecosystem disturbance from events like tephra fall, or from broader climate change like in the case of the Neoglacial. Ash particles from Hayes tephra ejections were potentially suspended in the atmosphere for days to weeks, and while human exposure to tephra is not directly fatal, inhaling tephra particles, especially for an extended period of time, is a health hazard. It takes as little as 5 mm of ash deposition to affect daily human activities. Tephra fall is considered a serious, but short-lived, human health hazard (Waythomas and Miller 2002; Wilcox 1959). The effects of tephra fall on human occupation of the study area needs to be explored further with multiple lines of evidence that assess local and regional effects of both climate change and tephra fall. The effect of ash fall on ecology and prehistoric people is an important research question, given the frequency of tephra events in Alaska.

Summary

Archaeological fieldwork associated with this study was limited to reconnaissance survey for and initial testing of archaeological sites. Additional testing may reveal denser deposits at some of the sites discussed here, and as we learn more about them, our interpretations may change. This study works under the assumption that the recovered assemblages represent close approximations of the intensity and location of hunter-gatherer activities in the study area.

The research contributes to our understanding of human use of southcentral Alaska by creating an AMS radiocarbon chronology of paleoecological, geomorphic, and archaeological events. The sample sizes are not sufficient to assess the chronology of human occupation with any finality, but it contributes to our growing knowledge of human use of upland landscapes. Specifically, the AMS dates presented here refine tephrochronology and archaeological chronology for the Susitna basin, beyond the earlier chronology developed for the middle Susitna that was based on bulk organic and standard radiometric analyses. Because the research presented here represents initial survey and testing of the study area, relatively small amounts of the sites were excavated, so interpretations of intensity of occupation have been based on amounts of artifacts recovered and cultural features identified per area excavated. These interpretations may change with expanded excavations.

Conclusions

This chapter has presented research directed at establishing the tephrochronological, geomorphic, and human occupation history of the upper Susitna River basin, Alaska. The results have important implications for explaining prehistoric upland use throughout the Alaska Range, as well as building a reliable tephrochronological framework for interpreting archaeological materials recovered from throughout southcentral Alaska. There are five main conclusions derived from this research:

1. Geomorphological data suggest that the last significant glacial ice sheet covering the study area receded by 14,000-13,000 cal BP, but that this glaciation may not have covered as much of the study area as previously thought. Following deglaciation, there is evidence for a period of high-energy aeolian activity in the study area represented by formation of the Susitna dune. Initial human occupation occurred during this time, by 11,000-10,500 cal BP.
2. There is evidence for human use of the study area from the early through late Holocene. Initial EH use appears to have been ephemeral, but intensified in the MH and LH. MH sites are characterized by denser

artifact deposits and cultural features, representing intensification of subsistence activities during this time. LH sites represent continued use of the study area, but with less dense sites, possibly representing a shift in subsistence activities during this time. Theses results are presented with the caveat that the archaeological sites presented here have been only initially tested, and additional research may reveal a more complex pattern of site occupation.

3. There are three, and possibly four recognized tephra falls represented in the upper Susitna basin; three of these correlate to the Oshetna, Watana, and Devil tephras identified in the middle Susitna basin, all likely products of the Hayes Volcano. The fourth possible tephra needs to be clearly characterized and its origin identified.
4. There is evidence for a hiatus in human occupation of the upper Susitna region during the MH, but it is unclear whether this is directly related to deposition of the Watana tephra; instead it may be related to Neoglacial Period climate instability, or it may simply be an artifact of sampling.
5. Future research will focus on exploring soil formation in the study area and its effect on field interpretation of tephra units and paleosols, geochemical and micromorphological exploration of the unnamed EH tephra fall, and a detailed, multi-faceted analysis of human use of the study area based on larger excavations and analyses of landscape use, lithic technology, and subsistence.

CHAPTER IV

PREHISTORIC LANDSCAPE USE IN THE UPPER SUSITNA BASIN, CENTRAL ALASKA RANGE

This chapter of the dissertation characterizes lithic assemblages from ten cultural components at eight Holocene-aged archaeological sites in the upper Susitna River basin in the central Alaska Range. The goal of this research has been to investigate hunter-gatherer lithic technological organization and land-use strategies in the uplands of the central Alaska Range, assessing how these strategies changed from the early Holocene through the late-prehistoric period, and how shifts in lithic technological organization and land-use were tied to changing environments and economies. A second goal has been to assess how lithic subsistence activities in upland landscapes condition lithic assemblage variability.

This study presents the conclusion that there were significant shifts in landscape use in the upper Susitna basin from long-distance logistical forays from residential camps outside of the study area in the early Holocene (EH), to short-distance logistical forays from upland residential camps and possible seasonal aggregation site in the middle Holocene (MH), to continued short-distance logistical forays from upland residential camps in the late Holocene (LH), but with a shifting to residential camps in alpine and lakeside settings. Throughout the Holocene, bifacial weaponry was preferred over microblade technology for upland subsistence activities, suggesting there is a link between landscape use in the central Alaska Range and hunting weaponry choice.

Background

Land-Use Strategies in the Upper Susitna River Basin

The ethnographic and ethnohistoric record of traditional use of the upper Susitna study area is important for developing a baseline understanding of the relationship between subsistence, landscape use, settlement patterns, and site location and function for hunter-gatherers in the study area. The Ahtna are members of the greater Athabascan language group of people traditionally inhabiting interior Alaska. Ahtna people have historically lived in a broad section of interior south central Alaska covering approximately 60,000 m^2, centered in the Copper River basin, and including the upper Matanuska, Talkeetna, and Susitna river drainages (Kari 2008; Simeone 2008). Historically, the Ahtna were subdivided into upper, lower, central, and western Ahtna territories; within each of these broader territories there were several bands with well-established territories where they conducted subsistence activities (Simeone 2008).

Ahtna language and dialect boundaries have been confirmed back to historic contact in the 1880's (Kari 2008). The Lower Ahtna occupied the Chitina and lower Copper River drainage; the Central Ahtna occupied the middle Copper River drainage west to Lake Louise, and the Gulkana and Gakona River drainages; the upper Ahtna occupied the upper Copper River drainage and upper Slana River; and the Western Ahtna occupied the western Copper basin west of Lake Louise and the upper Susitna and Matanuska river drainages (de Laguna and MacClelland 1981; Kari 2008; Simeone 2006).

Our knowledge of late prehistoric and contact period Ahtna life comes primarily from Ahtna oral history documented by important Ahtna informants like Jimmy Second Chief, Jake Tansy, Jim McKinley, Katie John, and Adam Sanford, and the written observations of Russian and Euro-American explorers (Irving 1957; Kari 2008, 2010; Reckord 1983). These sources of information primarily tell us about Ahtna life in the 1800s and 1900s. Traditional prehistoric lifeways in Alaska were significantly affected by Russian contact in the late 1700s and subsequent introduction of European trade goods and the exploitative fur trade economy in the 1800s, although this was often through indirect contact (Reckord 1983). The Yukon gold rush in the late 1800s resulted in direct contact between Ahtna and American settlers, and by the early 1900's there was a Euro-American mining camp established at Valdez Creek in the upper Susitna study area (Moffit 1912; Reckord 1983). Although subsistence and land-use patterns in the region changed during the protohistoric and historic periods, the information presented below is considered to be a reasonable approximation of late Holocene hunter-gatherer subsistence practices and landscape use in the study area.

Throughout Ahtna territory protohistoric and historic hunter-gatherers harvested fish, game, and wild plant resources in quantity in spring, summer, and fall, and built stores of these foods that were cached for survival during the winter. An important part of the annual Ahtna subsistence cycle targeted species when they migrated or congregated in large numbers. The two most important of these are the annual salmon run and caribou migration (Reckord 1983). There was interregional variation in the importance of each of these food items, as their abundance changed across ecological zones in the Ahtna territory. The Central and Lower Ahtna had access to rivers with spawning salmon, so the annual salmon run was the primary subsistence resource, along with moose, Dall sheep and caribou. The annual salmon spawn did not reach the river drainages of the Western and Upper Ahtna, who depended more on the annual caribou harvest and year-round harvest of whitefish as primary subsistence resources (Reckord 1983; Simeone 2006). Because of this interregional variation, this discussion of Ahtna subsistence and land-use patterns focuses primarily on the Western Ahtna, who had traditional ties to the upper Susitna study area (Figure 23), because their subsistence system would have been most closely adapted to the ecology of the study area.

The Western Ahtna territory is considered to be a more marginal environment than that of the Copper River Ahtna (Irving 1957). The place name for Western Ahtna band territory in Ahtna it is *Hwtsaay Nene'*; or "small timber country", and is described by the Ahtna as having broad stretches of tundra,

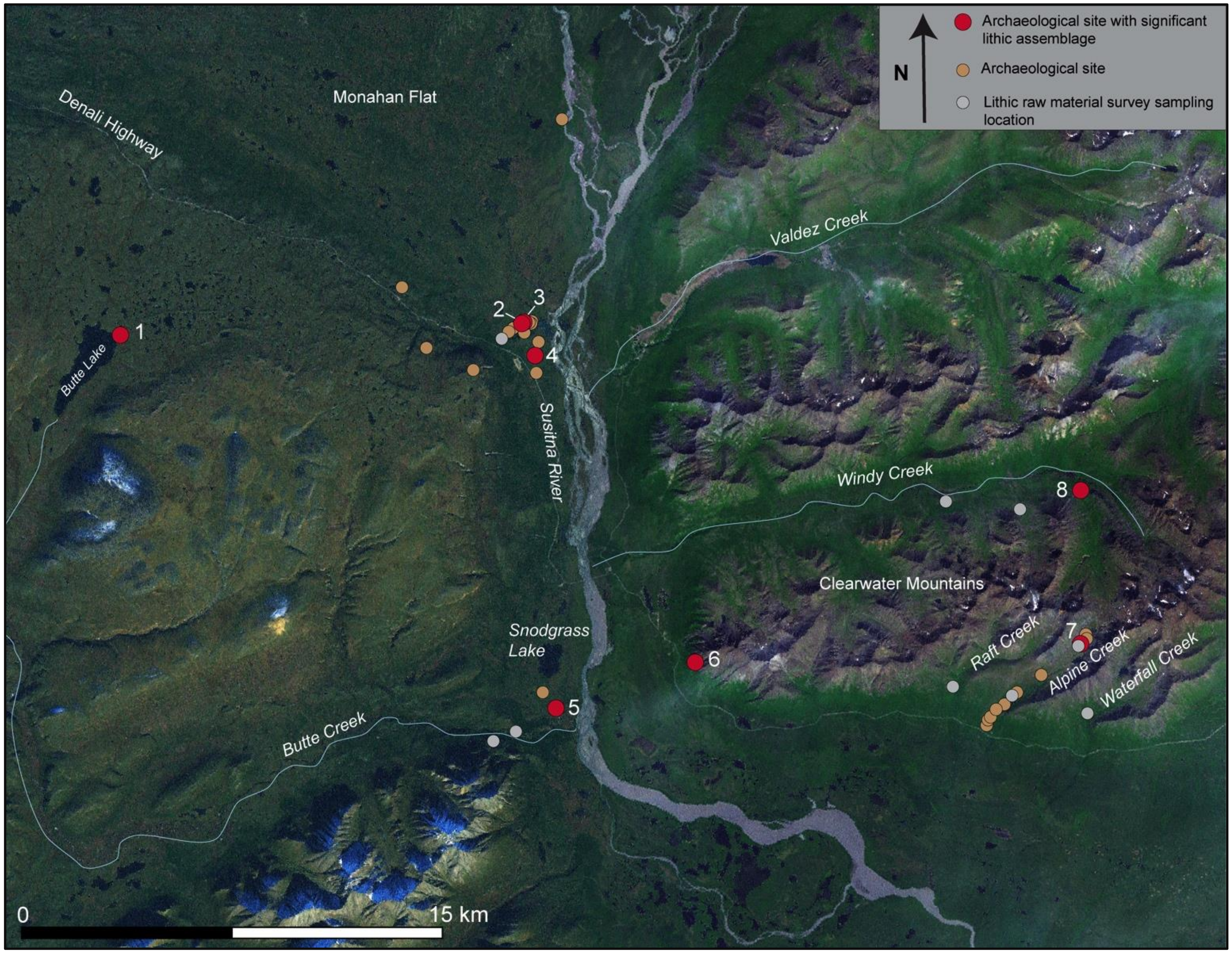

Figure 23. Map of upper Susitna study area showing sites described in text: 1, Butte Lake (HEA-189); 2, Susitna Dune 1 (HEA-454); 3, Susitna Dune 4 (HEA-508); 4, Susitna River 3 (HEA-455); 5, Butte Creek 1 (HEA-499); 6, Ratekin (HEA-187); 7, Alpine Creek 8 (HEA-460); 8, Windy Creek 1 (HEA-505).

lacking birch and large spruce trees, with no salmon but abundant caribou (Kari and Fall 2003). Important food resources in this environment included whitefish, trout, ling cod (*Ophiodon elongates*), grayling (*Thymallus arcticus*), caribou (*Rangifer tarandus*), moose (*Alces alces*), black bear (*Ursus americanus*), grizzly bear (*Ursus arctos*), muskrat (*Ondatra zibethicus*), beaver (*Castor canadensis*), rabbit (*Lepus americanus*), duck, geese, grouse, and ptarmigan.

Whitefish was a primary food item available throughout the year. Caribou and moose were hunted throughout the year, but focused hunting occurred in late summer when bulls were fat and skins were suitable for clothing (Irving 1957). Wetlands and kettle lakes in the upper Susitna basin provided habitat for large numbers of migrating waterfowl during the spring and fall seasons, and the Western Ahtna caught the molting birds and gathered their eggs. Blueberries and cranberries were abundant on hillsides in the late summer and were gathered and stored for winter consumption, and several types of edible roots and herbs were gathered (de Laguna and MacClelland 1981; Irving 1957; Reckord 1983).

Ahtna settlement patterns were organized around seasonal subsistence opportunities, and characterized by flexibility. Settlement types in the Ahtna seasonal round consisted of winter villages, hunting camps, and fishing camps (Reckord 1983). Site types associated with these activities included game lookouts, fall hunting camps, and fall and spring fisheries (Kari 2008). During periods of intensive harvesting such as the fall caribou drive, the Ahtna formed large task groups and settlement sites (both temporary and permanent). Often bands would congregate during these periods and work together to harvest caribou. Other subsistence activities, such as fishing and hunting camps, only required small groups and temporary shelters, leaving a small site footprint (Reckord 1983). Travel typically occurred on foot, but the trip from upland hunting camps to Copper Basin fish camps and winter villages sometimes occurred by canoe. Foot travel for distances of 100-130 km was considered routine (Irving 1957).

Western Ahtna band territories were typically organized around lake districts in the northwest Copper Basin, centered on lakes such as Paxson, Old Man, and Tyone lakes. Historic records indicate that Western Ahtna territory was centered between Tazlina Lake in the Copper River Drainage and Tyone Lake in the upper Susitna River drainage (DeLaguna and McClelland 1981; Kari 1977, 2008; Kari and Fall 2003). There are historic accounts of a large Western Ahtna village at the confluence of the Tyone and Susitna rivers that was a fur trade center during 1800s (Kari and Fall 2003; Reckord 1983). Irving (1957) estimated post-contact population at Tyone Lake to be no more than 100 persons, consisting of several bands of 5-30 individuals. Permanent winter villages, fishcamps, and hunting camps were situated within a relatively small area surrounding these lake districts, representing the nucleus of a larger hunting territory centered around local routes of caribou migration (Reckord 1983).

Historically, the largest Ahtna constructions were winter houses, the largest of which housed as many as six nuclear families. The winter house was a 2.4x3.7-m semi-subterranean structure, with a central fire hearth and steam bath annex (steam baths were probably introduced through Russian contact) (de Laguna and MacClelland 1981; Reckord 1983). Winter villages were located nearby rivers and lakes (de Laguna and MacClelland 1981; Irving 1957; Kari 1977; Moffit 1912; Reckord 1983). At winter villages the Western Ahtna fished through the ice for burbot, lake trout, and steelhead trout (Simeone 2008). Ice fishing was often crucial for late winter survival (de Laguna and MacClelland 1981). By midwinter the shallow lakes in the region had frozen to the bottom and cached meat supplies were running low, so late winter subsistence focused on hunting of caribou, moose, bear, and beaver, as well as trapping (Irving 1957). In historic times, families often had smaller log and moss houses deep in woods that were occupied during late winter hunting season (de Laguna and MacClelland 1981).

Following breakup in the spring, the Western Ahtna would disperse from their winter village a few km to fishing camps along rivers. Fish were harvested using weirs and fish traps; fish camps were characterized by temporary shelters, often re-used, and frequently contained materials such as fish traps and spears cached nearby. The Western Ahtna would disperse into upland hunting camps in the late summer and early fall. Fishing for whitefish continued nearby upland hunting camps, and ground squirrels were snared above treeline during this time

(Reckord 1983; Simeone 2008). While occupying summer hunting and fishing camps, dwellings typically consisted of temporary structures like a lean-to or simple brush shelter (de Laguna and MacClelland 1981). Hunting camps were in higher elevations and often located near specific game locations, as many as 80 km from the winter village. Smaller hunting camps were often established away from the main hunting camp to target species like moose, while larger groups congregated for caribou hunting (Reckord 1983).

The headwaters of the Yanert Fork in the Alaska Range and the Jack River in the Talkeetna Mountains were known as preferred summer hunting grounds, particularly for caribou, but Dall sheep were also available at the headwaters of the Yanert Fork. Caribou meat was typically cached in these river valley bottoms for recovery during the winter months. The headwaters of the Susitna River were known as a good area for moose and caribou. Caribou traveled across the region throughout the year, and were hunted year round. Butte Creek, Deadman Creek, and Jack River were known as good grayling streams, and the Western Ahtna considered Butte Lake to be good for all fishing, especially trout (Irving 1957; Kari 2010; Moffit 1912; Reckord 1983).

The ethnographic and historic records of Western Ahtna subsistence indicate that protohistoric and historic subsistence practices were heavily influenced by seasonal resource availability in the lowlands of the western Copper basin and upland upper Susitna River basin and Talkeetna Mountains. The Western Ahtna commonly moved to spatially and temporally discrete subsistence resources, focusing on resources during periods of abundance, and utilizing methods like fish weirs and drivelines to procure large quantities of resources to serve as stores for consumption during winter months. Caching resources like caribou, fish, and berries procured during times of abundance was of critical importance to this subsistence strategy.

The subsistence strategy described for protohistoric and historic Western Ahtna hunter-gatherers is typical of a logistically-oriented subsistence system. Logistical mobility is a response to spatially and temporally inconsistent resources, a shorter growing season, and/or a harsher climate that requires critical dependence on stored food resources (Binford 1980). The Western Ahtna winter villages fit the description of long-term (seasonally) base camps in a logistically mobile system, while fish camps and hunting camps fit the description of field camps. In addition, large camps as described for fall caribou hunting are typical of a logistical system. In a logistical system, there are a variety of site types, the more components of a logistical system in a subsistence strategy, the greater the inter-site variability. This contrasts with a more residentially mobile system, in which food is searched for on an encounter basis, sites are not functionally specific, and variability represents seasonal scheduling of subsistence activities and duration of occupation duration (Binford 1980).

Western Ahtna Caribou Hunting. Historically, the Nelchina caribou herd has been the primary caribou herd in southcentral Alaska (Hemming 1971;

Skoog 1968). Nelchina herd movement and timing can vary significantly year to year. Variables such as forest fires, available biomass, weather, predation, and herd size can affect herd movement patterns (Hemming 1971; Joly et al. 2003; Schwanke 2011; Toobey 2009). Historic records of the Nelchina caribou herds movement indicate that the herd offers a fairly consistent subsistence resource. Historic accounts of caribou provide evidence that herd size, location, and movement were variable from year to year, with the caveat that these accounts are non-scientific surveys with limited sampling and little access to most of the territory used by caribou. There are several recognized historical cycles of population growth and decline as well as expansion and contraction of the winter range for the Nelchina herd. These data indicate that caribou can be a somewhat spatially unpredictable resource (Hemming 1971, 1975; Pitcher 1984; Schwanke 2011; Skoog 1968; Toobey 2009).

Based on ethnohistoric accounts, caribou hunting occurred throughout the year, but using different approaches. During the fall drive, caribou were often hunted by large groups consisting of several Ahtna bands, who congregated at drive lines or by driving caribou into lake and spearing from a skin boat (Reckord 1983). Throughout the rest of the year, smaller, dispersed bands hunted caribou as they were encountered (Irving 1957). Summertime is considered a good time to hunt caribou in the uplands, because caribou tend to congregate near ice patches. Ice patches with caribou have brown ice, making them easily distinguishable to hunters. Ice patch hunting of caribou would result in denser sites in alpine settings, situated nearby ice patches. Hunting equipment recovered from alpine ice patches indicates that atlatls dating between approximately 9400 and 1200 cal BP, bow and arrows (1200 to 130 cal BP), and hunting blinds were part of the alpine ice patch hunting strategy (Hare et al. 2004).

The distinct seasonal subsistence round described for the Western Ahtna is an adaptation to the strong seasonal availability of subsistence resources and the need to cache food and establish more substantial, semi-permanent residences to survive the harsh winter period. One of the primary goals of this research is to assess prehistoric land-use patterns and assess when this strong seasonal landscape-use pattern emerged by investigating archaeological sites in the upper Susitna River basin study area.

Prehistoric Subsistence and Landscape Use. The earliest evidence for human occupation of central Alaska comes from the Tanana Valley lowlands (Figure 1) where at Swan Point cultural material has been dated to 14,200 cal BP (Holmes 2001, 2011). Nearby, Broken Mammoth, Mead, Upward Sun River, and McDonald Creek provide further early evidence of humans in the Tanana Valley lowlands between about 14,000-13,200 cal BP (Goebel et al. 2014; Holmes 2001; Potter et al. 2011). In the neighboring foothills of the Nenana and Teklanika valleys, the earliest evidence for humans is at Dry Creek, Walker Road, Owl Ridge, and Moose Creek, all dating to 13,400-13,000 cal BP (Graf et al. 2015; Graf and Bigelow 2011; Pearson 1999; Powers and Hoffecker 1989).

Contrastingly, the earliest evidence for human occupation in the Alaska Range is at Eroadaway (12,750 cal BP) and Bull River II (12,460 cal BP) (Holmes et al. 2010; Wygal 2009, 2010).

Following the earliest evidence of human use of the central Alaska Range at Eroadaway and Bull River II, there is evidence of upland use at the Tangle Lakes sites of Phipps, Whitmore Ridge, and Sparks Point, all dating between 12,000 and 10,300 cal BP (West et al. 1996a, 1996b, 1996c), as well as in the upper Nenana valley at Carlo Creek (11,300 cal BP) (Bowers and Reuther 2008). There is no evidence for sustained use of the uplands during the late Pleistocene (LP) and EH, only sites reflecting short-term, abbreviated occupations (Graf and Bigelow 2011; Mason et al. 2001).

Some studies suggest the archaeological record indicates that hunter-gatherers prior to 6000 cal BP concentrated subsistence activities in the lowlands, maintaining a generalized economy targeting bison, wapiti, and birds year-round, from short-term, open-air camps (Potter 2008a, 2008c; Potter et al. 2014). This has been contradicted by one study that points to the variety of faunal taxa represented at the Broken Mammoth site as evidence for utilization of various microenvironments during the LP/EH, including upland procurement of marmot, Dall sheep, and possibly caribou (Yesner 2001), and by speculation that LP/EH upland landscapes were an important part of early central Alaskan human subsistence, but that we do not yet know the extent of LP/EH upland use because sites representing this activity are from undated surface contexts or are undiscovered (Wygal 2009).

Other researchers agree that during the Bølling-Allerød interstadial (14,700-12,900 cal BP) (Rasmussen et al. 2006) inhabitants of the lowlands and foothills of the Tanana and Nenana valleys in central Alaska had low mobility, procured a variety of resources, including small and large game throughout the year in the lowlands, and used foothill locations to procure large ungulates during the autumn rut. These people were seemingly operating as low mobility, logistically organized collectors, tethered to local resources, probably using the lowlands year-round and seasonally foraying short distances into the uplands to procure seasonally available resources (Graf and Goebel 2009; Graf and Bigelow 2011).

However, several studies suggest that there was a significant shift in land-use strategy accompanying cooler and dryer conditions during the Younger Dryas (YD). During this time subsistence activities shifted to focus on larger game, including hunting bison, wapiti, and occasional caribou and waterfowl in the lowlands during the late summer and early autumn, and late-autumn and early-winter hunting of bison in the foothills and Dall sheep in the foothills, and uplands. This mobile strategy included provisioning with local as well as non-local lithic raw material resources and production and maintenance of formalized toolkits (e.g., microblades), and may have focused on following mobile herd populations of bison, wapiti, and caribou (Graf and Bigelow 2011; Graf and Goebel 2009; Mason et al. 2001).

The shift from a less mobile to more mobile landscape-use strategy was likely in response to a vegetative shift from a mixed shrub-tundra biome with a variety of resources during the warm and mesic Bølling-Allerød, to an increased grass and forb biome accompanying cooler, drier conditions more favorable for mobile herd animals such as bison, wapiti, and caribou during the YD. Increased upland subsistence activity during the YD is supported by the earliest archaeological sites in the uplands of the central Alaska Range at Eroadaway and Bull River II. Following the YD, as climate warmed and became more mesic and boreal forest spread from the lowlands into the foothills and uplands, hunters appear to have abandoned the foothills and uplands and re-focused subsistence activity in the lowlands (Graf and Bigelow 2011), possibly even abandoning many previously inhabited areas of interior Alaska as population declined in response to lower carrying capacities in the spruce forest biome (Mason et al. 2001; Potter 2008a, see also Bever 2006). However, it has been suggested that the apparent population collapse associated with the spread of spruce forest may be an artifact of taphonomic loss, as geomorphic processes during the EH would have destroyed or deeply buried archaeological sites (Mason and Bigelow 2008).

Beginning in the MH approximately 6000 cal BP, archaeological data suggest a gradual increase in population as hunter-gatherers successfully adjusted to forested conditions by shifting to a logistically mobile settlement system, focusing on seasonal resources like caribou and fish, and increasingly using the uplands (Potter 2008a, 2008b, 2008c). During the late Holocene (LH) (~1200 cal BP), there appears to have been a further shift to seasonally specific residential habitation sites and continuing logistical mobility, evidenced by the presence of house pits and cache pits at sites dating to this time period (Potter 2008a, 2008b, 2008c). Several studies suggest issues with this characterization of landscape use; some have questioned the correlation of spreading populations adapted to the spruce forest, as many sites during this period occur in the boreal/tundra ecotone or shrub tundra (Esdale 2008; Mason and Bigelow 2008). There is also an apparent lack of storage features at archaeological sites during the MH, contradicting the hypothesized shift towards a logistically mobile settlement strategy (Mason and Bigelow 2008).

Another factor potentially causing changes in human landscape use was volcanic eruptions. There is evidence that volcanic effects, including ash falls, had a negative impact on fauna and flora, subsequently affecting human population demographics (Mullen 2012; VanderHoek 2009). There is evidence of significant MH/LH ash fall in the central Alaska Range several times during the Holocene (Begét et al. 1991; Dilley 1988; Dixon and Smith 1990; Wallace et al. 2014), indicating that this may have played a part in landscape evolution and human use. These contrasting interpretations begs the question: what was the nature of upland use throughout prehistory – was it always as in ethnographic times, or was there gradual change related to large scale climate and vegetation change, or cyclical changes resulting from volcanic ash fall? Did upland use consist of occasional/seasonal hunting forays or more permanent settlements?

Central Alaskan Lithic Assemblage Variability

Central Alaska has a unique and diverse archaeological record, with significant spatial and temporal variability in lithic assemblages highlighted by preferential use of bifacial versus inset-microblade projectile technology (Goebel and Buvit 2011; Hoffecker and Elias 2007). Early research focused on temporal differences in these technologies, attributing variability to different cultural groups living in Alaska at different times (Dixon 1985; Goebel et al. 1991; Hoffecker et al. 1993; Pearson 1999; Powers and Hoffecker 1989); however, subsequent research has revealed a more complex picture (Holmes 1996, 2001, 2011; Holmes et al. 1996; Potter 2008a), attributing variability to different behaviors not necessarily related to cultural historical ties (Potter 2005, 2008a, 2008b, 2008c, 2011; Rasic and Andrefsky 2001; Robinson 2008; Wygal 2009, 2010). Recent research has focused on identifying behaviors that left patterning in the archaeological record, tying lithic assemblage variability to changing prehistoric economies, seasonal landscape use, and lithic raw material variability on different landscapes.

Current research in Alaska indicates that lithic technological choices were conditioned by seasonal subsistence activities in upland and lowland landscapes, as well as lithic raw-material availability (Potter 2005, 2008c, 2011; Wygal 2009, 2010). Inset-microblade technology may have been more reliable and conserved raw material more efficiently than bifacial technology during winter, when stone became brittle and hard to find under snow cover, and lowland bison, moose, and wapiti were procured. Conversely, bifacial points may have been preferred for caribou and sheep hunting during summer, when raw material was readily available and there was less risk of cold-failure (e.g., Elston and Brantingham 2002; Flenniken 1987; Wygal 2009, 2010). Inset-microblade points may also have been used as thrusting spears to hunt lowland bison, moose, and wapiti in the fall-winter-spring, while bifacial points were preferred for hunting caribou and sheep in the uplands in the summer (Potter 2008c, 2011).

The technological switch to microblades in the Younger Dryas may be related to risk reduction in hunting large-bodied herd animals like bison. The faunal record supports this, as bison are commonly found in YD assemblages (Graf and Bigelow 2011). The emergence of various new bifacial point forms in the MH may be linked to a shift in landscape use highlighted by expanded use of the uplands, in particular caribou hunting (Potter 2008c). Variation in subsistence/settlement system, mobility, and seasonal task scheduling certainly impacted human technologies; therefore, understanding tools and toolkits within the adaptive system in which they occur will lead to a more robust explanation of assemblage variability (Goebel and Buvit 2011; Potter 2005, 2008a, 2008c).

Lithic assemblage variability in response to landscape use is testable: there is an expectation that upland sites should be dominated by bifacial technology utilizing local raw-material, while lowland sites should be dominated by microblade technology utilizing exotic raw material (Potter 2011; Wygal 2009). Addressing the validity of this hypothesis requires a regional approach incorporating evidence of prehistoric landscape use and assemblage variability from both the central Alaskan lowlands *and* uplands. As it stands now, most of the archaeological evidence we have at hand comes from research in the Tanana and Nenana lowlands and foothills, while in the uplands of the Alaska Range, few sites have been well-documented (but see Coffman 2011; West et al. 1996a, 1996b, 1996c; Wygal 2009, 2010). Previous research leaves us with the important question: How did upland subsistence activities condition lithic assemblages in the study area?

Lithic Technological Organization

This study considers variation in upland central Alaskan lithic assemblages (technological and typological) from an adaptive, technological-organization perspective. In particular, this study focuses on understanding human strategies employed during stone-tool manufacture, use, transport, and discard, as well as strategies used to obtain toolstone (Nelson 1991). Hunter-gatherers used different technological strategies to extract food resources in response to situational environmental constraints; therefore, lithic technology needs to be understood in the context of the environment (Binford 1977, 1980; Nelson 1991). When lithic raw material access is controlled for (Andrefsky 1994, Bamforth 1990), technological-organization studies can help interpret the relationship between the structure of subsistence resources and human land-use patterns (Binford 1977, 1980; Kelly 1983, 1985, 1988; Kuhn 1995; Shott 1986).

The lithic analysis presented here considers toolstone procurement, primary reduction technologies, secondary reduction technologies, and tool production and use to help delineate organization of technological activities and ultimately to understand provisioning and mobility strategies. Lithic technological studies grounded in ethnographic research, actualistic studies, and controlled archaeological case studies have delineated expectations for lithic artifact assemblages produced within highly mobile versus low mobility land-use systems (Kelly 1992, 2001; Kuhn 1995; Parry and Kelly 1987). The lithic assemblage expectations used for this study are presented in Table 1. At the core of these expectations is the idea that hunter-gatherers make technological decisions balancing cost (time to procure lithic raw material, manufacture time) and utility (efficiency of a tool to perform a task).

Table 1 presents archaeological expectations for lithic assemblages produced by hunter-gatherers occupying the upper Susitna study area, first as short residential stays as part of a high residentially mobile system, and second as a long-distance logistical resource extraction camp, operating from a base camp in the lowlands. Expectations for archaeological assemblages produced in

Table 12. Archaeological expectations for lithic assemblages produced in different land-use systems (Binford 1980, Kelly 1992, 2001; Kuhn 1995).

	High residential mobility (foragers) or highly mobile logistical forays provisioning individuals	Low residential mobility (collectors) provisioning place
Lithic raw material procurement		
Percent local lithic raw material	Low	High
Long distance transport	Some	None
Amount of cortex	Low	High
Quality of lithic raw material	High, plus whatever is locally available	Low to high depending on quality of locally available material
Raw material selection	Yes	No
Primary reduction		
Primary reduction debitage	Less frequent, formal	More frequent, informal
Formal:informal core ratio	High	Low
Technical debitage	Common	Rare
Formal tool blank production	Common	Rare
Bipolar knapping, tool recycling/ scavenging	Rare	Rare to common, depending on length of occupation
Secondary reduction; tool production and use		
Secondary reduction debitage	Common	Rare to common (depending on length of occupation)
Formal:informal tool ratio	High	Low
Reduction intensity	High	Low to high (depending on length of occupation)
Tool:debitage ratio	High	Low
Complete:broken tool ratio	Low	High
Tool function	Both specialized and multi-purpose	Specialized
Tool weight	Light	Heavy
Site characteristics		
Assemblage diversity	Less diversity	More diversity
Site density	Low	High
Within-site variability	High	Low
Between-site variability	Low	High
Fire-cracked rock	Rare	Common

these two types of high mobility settlement systems are similar; hunter-gatherers are expected to provision individuals by carrying lithic raw material and tools in anticipation of future use. Lithic raw material in these systems should be predominantly high-quality, non-local material, supplemented with some poorer quality, locally available material. Formal cores are produced to maximize utility by maximizing the number of flakes available from toolstone.

Primary reduction should focus on producing and maintaining formal cores, producing formal tool blanks and formal tools. Formal cores are made in anticipation of use and designed to be maintainable and maximize the number of flakes available from lithic raw material. Secondary reduction should show a high incidence of bifacial and unifacial tool maintenance. Tools come in both specialized and multi-purpose forms, are maintained and heavily reworked, and are frequently transported. Overall the toolkit in a system that provisions individuals is light, portable, durable, and generalized enough to serve many purposes. This system is geared towards unpredictable resource encounters, and works best for groups with a high number of residential moves and shorter occupation span, with unpredictable tool and toolstone needs (Kelly 1988, 2001; Kuhn 1995).

In a settlement system with low residential mobility (provisioning place), lithic technology is focused on equipping the location where tools will be used, so archaeological assemblages are expected to comprise primarily locally available lithic raw material, with perhaps some evidence of stockpiling of nonlocal raw material. Core reduction techniques are informal, with little investment in design, and provide flexibility to make tools with a wider range of functions. Primary reduction focuses on producing and reducing informal cores, producing informal tool blanks and tools; secondary reduction focuses less on bifacial and unifacial tool maintenance; and tools come in specialized forms, are infrequently maintained, and are often discarded on-site. Overall the toolkit in a system that provisions place is heavier, less durable, less portable, expedient, and specialized, with a variety of tool types. This system is geared towards predictable resource encounters, by groups with landscape knowledge that conduct a variety of tasks at precisely known locations, and works best for groups with a low number of residential moves and longer occupational spans (or frequent reoccupation), with predictable tool and toolstone needs (Kelly 1988, 2001; Kuhn 1995).

It is important to remember that settlement organization occurs on a continuum, and the expectations presented in Table 12 represent ideal ends of this continuum. The archaeological assemblages presented here are not expected to fit perfectly into one category or another; rather these idealized expectations are designed for comparison to archaeologically derived lithic assemblages. Lithic assemblage attributes are presented here to assess whether hunter-gatherers exploited the uplands in a pattern of high residential mobility or long-distance logistical forays from lowland camps, provisioning themselves with the lithic raw materials necessary for subsistence activities, or in a pattern of low residential mobility from camps in the uplands, provisioning base camps with the lithic raw material necessary for subsistence activities, and whether these strategies changed over time.

Methods

Lithic Landscape Survey

This study assessed lithic raw material sources available in the upper Susitna study area by consulting geologic maps of the study area, and documenting and sampling knappable lithic raw materials present in drainages throughout the study area. This approach has proven successful for identifying locally available lithic raw material sources in Alaska (Graf and Goebel 2009). The lithic raw material survey undertaken for this study was limited to drainages that were accessible by road or one-day hike from a road, so the results presented here are not to be taken as an exhaustive survey of the available lithic raw material resources available in the study area. Samples of lithic raw material types collected in the field were transported back to Texas A&M University, where they were used as a comparative reference collection for provenance analysis of lithic material from archaeological contexts in the study area.

This study used a suite of physical characteristics to describe each lithic raw material sample. Lithic raw material color was assessed using a Munsell Rock color book (Munsell Color 2012). Lithic raw material texture was assigned to one of three texture categories: macrocrystalline (texture/grains visible with naked eye), microcrystalline (texture/grains visible at 10x), and cryptocrystalline (texture/grains visible at 40x). Texture characteristics are used here as a qualitative measure of mechanical properties and overall knapping quality of lithic raw materials (cf. Luedtke 1992). Nodule size was measured using a linear dimension; this measurement was used to assign nodules to pebble, cobble, and boulder classes (Wentworth 1922). Size class data provide information on the available package size of lithic raw materials in the study area. Cortex type was scored as either primary (geologic) cortex or secondary (stream-rolled) cortex following Rasic (2008:225).

Lithic raw material class was assessed using rock identification guides (e.g., Proctor et al. 1989). Lithic raw material classes were further separated into types based on color and composition. Lithic raw materials were separated into classes for discussion purposes, but rock genesis can be complicated, and without further analyses (e.g., thin-sectioning) these were considered approximate categories. Physical characteristics of lithic raw material types were used to connect lithic raw materials from archaeological contexts with lithic raw material sources in the study area, to better understand local and non-local raw-material transport as a component of lithic-technological-organization strategies. This study designates toolstone available within the study area (Figure 23) as local and beyond approximately 20 km as nonlocal.

Lithic Analysis

The lithic assemblages presented here were primarily recovered during field research conducted from 2010-2012 at Susitna Dune 1 (HEA-454), Susitna River 3 (HEA-455), Butte Creek 1 (HEA-499), Susitna Dune 4 (HEA-508), Alpine Creek 8 (HEA-460), and Windy Creek 1 (HEA-505) (Figure 23). A detailed description of the results of archaeological field investigations can be found in Chapter III. This study focuses on lithic assemblages from eight cultural components at these six archaeological sites. These materials represent the most significant lithic assemblages (generally components with more than 200 lithics) recovered from the study area. In addition, this study includes assemblages from three cultural components at two previously investigated sites in the study area, Butte Lake (HEA-189) (Betts 1987; Wendt 2013) and the Ratekin site (HEA-187) (Skarland and Keim 1958), analyzed by the author at the University of Alaska Museum of the North (UAMN) in 2012-2013.

All debitage and tools were analyzed using metric and non-metric attribute analysis. Digital calipers, a digital goniometer, and a digital scale were used to collect metric data, and visual inspection was used to collect non-metric data. Lithic raw-material classes and types were evaluated as described above. Lithic raw material types were then visually compared to lithic raw material samples collected during our raw material survey of the study area, as well as to Alaska lithic raw material reference collections at Texas A&M University. Obsidian artifacts measuring at least 1 cm in maximum dimension and 3 mm thick were analyzed using a portable X-ray fluorescence (PXRF) device at UAMN; the goal of this analysis was to measure trace-element concentrations to determine the geologic formation the obsidian originated from (cf., Glasscock et al. 1998, Reuther et al. 2011). All obsidian PXRF geochemical characterization results are presented with Alaska Obsidian Database (AOD) reference numbers.

Debitage attributes scored in this study include weight (to the 0.1 g), size class (very small = 0-1 cm, small = >1-3 cm, medium = >3-5 cm, large = >5 cm), condition (proximal or flake shatter, proximal flakes scored as complete or broken), amount and type of cortex, platform preparation (e.g., cortical, smooth, complex, lipped), and presence/absence of thermal alteration. Debitage was also classified using a hierarchical typology, separating pieces at two levels, class and type. Debitage typology characteristics follow Andrefsky (2005) and Graf (2008) (Table 13). Debitage attribute and typological scores are used to interpret lithic raw material provisioning and the technology used for production and maintenance of stone tools. Incorporating both attribute and typological analytical strategies in tandem increases the reliability of technological activities interpreted from the debitage assemblage (Andrefsky 2005).

For this study cores were grouped into formal and informal categories, measuring the number of platforms, platform-surface preparation, number of core fronts, maximum linear dimension, weight, and size value. Formal cores were characterized according to morphological features (Andrefsky 2005). Informal core types presented here include simple flake core, bipolar core, and multidirectional core. Formal core types include bladelet core and microblade core.

Table 13. Debitage type descriptions presented in this study.

Debitage class	Debitage type	Type description
Primary reduction flake	Flake fragment	Distal flake fragment (no striking platform) with no cortex >1 cm in size
	Core reduction flake	Proximal flake fragment with no cortex, typically with a smooth platform, and >1 cm in size
Cortical spall	Cortical spall fragment	Distal flake fragment with any amount of cortex on dorsal side
	Primary cortical spall	Proximal flake with ≥50% cortex on dorsal side
	Secondary cortical spall	Proximal flake with ≤50% cortex on dorsal side
Secondary reduction flake	Retouch chip fragment	Distal flake fragment with no cortex that is thin and <1 cm in size
	Retouch chip	Proximal flake with no cortex that is thin and <1 cm in size
	Biface thinning flake	Proximal flake with no cortex and a complex and/or low-angled platform >1 cm in size
Shatter	Shatter	Angular pieces with no clearly defined ventral surface.
Gravel	Unworked gravel	Unaltered pebble or cobble-size gravel of knappable lithic raw material
	Initially flaked gravel	Pebble or cobble-size gravel with ≤3 flake removals
Bladelet	Bladelet fragment	Distal blade fragments with widths <20 mm and irregular lateral margins
	Bladelet	Proximal blade fragments with widths <20 mm and irregular lateral margins
Microblade	Microblade fragment	Distal blade fragments that are thin with a triangular, trapezoidal, or five-sided cross section and with widths <8 mm and parallel lateral margins
	Microblade	Proximal blade fragments that are thin with a triangular, trapezoidal, or five-sided cross section and with widths <8 mm and parallel lateral margins
Burin spall	Burin spall	Typically narrow and thick, often triangular in cross section, terminating in a hinge or step; removal from the burination of a tool
Technical debitage	Bladelet core trimming flake	Detached pieces that typically have several parallel negative bladelet scars on the dorsal face. Core trimming flakes were removed from the front of a bladelet core to rejuvenate the core front for further bladelet removals
	Microblade core tab	Typically blocky with dorsal surfaces representing the core platform the piece was removed from. Lateral margins show negative microblade imprints typically perpendicular to the flake axis, representing microblades removed from the core front
	Microblade core trimming flake	Detached pieces that typically have several parallel negative microblade scars on the dorsal face. Core trimming flakes were removed from the front of a microblade core to rejuvenate the core front for further microblade removals

Tools were classified as unifacial or bifacial, and non-metric and metric attributes were recorded for each including weight (to the 0.1 g), tool condition (complete, proximal, medial, distal, edge fragment, etc.), fracture type, edge angle (measured to the 0.01°), tool-blank type and presence/absence of hafting characteristics. Tool blanks are grouped into formal (biface, biface thinning flake, blade, bladelet, microblade, burin spalls, and cores) or informal (cortical spall, flake, blade-like flake) types.

Unifacial tools were scored for invasiveness of retouch (measured to the 0.01 mm at the most invasive depth, and at 25%, 50%, and 75% of tool face when these portions of the tool face were available), and retouched edge angle. Unifacial tool retouch intensity was scored as the number of retouched edges out of 10 units representing the entire circumference of the tool, excluding missing tool edges (following Surovell 2003, 2009). Unifacial tool retouch intensity is presented here as the percent of retouched edge units out of the number of available edge units. Available edge units include all edge units not comprised entirely of a break edge. Small unifacial tool edge fragments less than one edge-unit in size were not included in this analysis.

The remaining utility in discarded unifacial tools (including retouched flakes and blades, end scrapers, and side scrapers) was calculated with a reduction index. This measurement used depth of retouch (the mean of the four invasiveness scores described above), retouched edge angle (measured to the nearest 1° at the point of most invasive retouch), and tool thickness to calculate a retouch index using the formula (sine edge angle)(depth of retouch)/thickness of tool (following Kuhn 1990).

Tools were classified as formal or informal. Formal tools are those tools manufactured in anticipation of use to have a long use-life and possibly serve multiple functions; formal tool types presented in this study include biface, end scraper, side scraper, multiple spurred graver, burin, and combination tool. Informal tool types include single-spurred graver, retouched flake, retouched blade, retouched microblade, retouched burin spall, knife, and cobble tool.

Tools were scored typologically into class and type, using a standard typology developed for sites in central Alaska (Goebel et al. 1991). Bifacial tools were further categorized into hafted and unhafted categories (based on presence absence of edge grinding and hafting characteristics such as flake arris wear, indentation from grinding/wear, notching, and blade indentation from sharpening in the haft), and scored for length, width, thickness (mm), weight (0.1 g), fragment type, transverse and longitudinal cross section, presence or absence of cortex, edge shape, presence/absence and length of marginal grinding, hafted biface basal shape and basal features, and flaking pattern.

Because of the overall small number of unhafted bifaces presented here, basic reduction categories were used to characterize reduction sequence. Early stage bifaces were initially flaked along edges, with few flake scars across the face; middle stage bifaces have most cortex removed and are flaked across the face to the center of the tool; late stage bifaces have a flat cross section, large, flat flake scars across the faces; finished bifaces have all of the characteristics of late stage bifaces, along with refined edge trimming (typically used for bifacial tool fragments that are missing the proximal end and therefore cannot be definitively assigned to hafted biface category).

Tool-to-debitage ratio was calculated to indicate how tools were carried onto sites and which tools were made on site (Kelly 2001:229). Tool richness, an assemblage-level measure of tool diversity, was calculated for each component. Tool richness was calculated by plotting the number of tools in an assemblage by the number of tool types in the assemblage (Grayson and Cole 1998; Kintigh 1984; Odell 2004:111). This method has been used effectively to determine whether tool assemblages represent activity at a residential base camp or logistical resource extraction camp (Graf 2008, 2010). For this analysis, biface stages were counted towards the total tool count, and each stage was considered a tool type.

The lithic assemblage analytical methods presented here are used to reconstruct lithic raw material procurement, lithic reduction activities, and tool use-life histories; these lithic technological activities are used to interpret settlement organization and land-use strategies. Local vs. non-local lithic raw material procurement was assessed by comparing lithic raw material types in archaeological assemblages with lithic raw material types collected during our lithic raw material survey of the study area. In addition, the amount of cortex in lithic raw material types was used as a measure of locally available or stockpiled lithic raw materials. Primary reduction refers to core preparation and tool-blank manufacture, and was used to assess the formality of core reduction at each site. Secondary reduction refers to tool sharpening and re-sharpening, and was used to assess the amount of energy invested in maintaining toolkits at each site. Tool production describes the types of tools produced at each site, focusing on whether the tools produced at each site are expedient or formal, and whether tools are specialized or multifunctional. Tool analysis also focused on the intensity of tool retouch and state of discard.

Upper Susitna Study Area Lithic Landscape

The lithic landscape of the upper Susitna study area consists of stream-rolled gravels available in secondary outwash, moraine, alluvial, and dike deposits, as well as primary geologic toolstone outcrops, many of which contain potentially knappable lithic raw materials (Kachadoorian et al. 1954; Mooney 2010; Smith 1981; Smith et al. 1988). Lithic raw material resources in the study area are best described separated into three portions of the study area: the Clearwater Mountains in the eastern portion of the study area, the Butte Creek drainage in the western portion of the study area, and Quaternary surficial deposits located throughout the entire study area (Figure 23, Table 14).

Table 14. Lithic raw material survey results; see Figure 23 for sampling locations.

Survey Location	Raw Material Type	Munsell Rock Color	Texture[1]	Nodule Size[2]
Raft Creek	Metavolcanic	Grayish Red (5R 4/2)	MA to MI	PE to CO
	Metasedimentary	Medium Dark Gray (N4)	MA to MI	PE to BO
	Metasedimentary	Dark Gray (N3) to Medium Dark Gray (N4) with White (N8) banding	MI	PE to CO
	Quartzite	Medium Bluish Gray (5B 5/1)	MA	PE to CO
Waterfall Creek	Metavolcanic	Dark Greenish Gray (5GY 4/1)	MA to MI	PE to CO
	Metasedimentary	Dark Gray (N3)	MI	PE to CO
	Metasedimentary	Medium Dark Gray (N4)	MI	PE to CO
	Metasedimentary/quartzite	Dark Greenish Gray (5GY 4/1)	MA to MI	PE to BO
	Metasedimentary/quartzite	Grayish Green (5G 5/2), Pale Olive (10Y 6/2)	MI	PE to CO
	Metasedimentary	Medium Bluish Gray (5B 5/1)	MI	PE to CO
	Metasedimentary	Light Bluish Gray (5B 7/1) to Dark Greenish Gray (5G 4/1)	MI	PE to CO
	Metachert	Moderate Reddish Brown (10R 4/6)	CCS	PE
	Chalcedony	Medium Dark Gray (N4)	MI	PE
Alpine Creek	Metasedimentary/quartzite	Dark Greenish Gray (5GY 4/1)	MA to MI	PE to BO
	Metasedimentary	Dark Greenish Gray (5GY 4/1)	MA to MI	PE to BO
	Chert	Grayish Black (N2)	MI	PE to CO
	Metasedimentary/quartzite	Dark Greenish Gray (5G 4/1)	MI	PE to BO
	Metasedimentary/metachert	Dark Greenish Gray (5G 4/1)	CCS	PE to BO
	Metasedimentary/ tuffaceous argillite	Pale Olive (10Y 6/2), Dark Greenish Gray (5GY 4/1)	MI to CCS	PE to BO
	Metabasalt	Grayish Red (10R 4/2), Pale Olive (10Y 6/2)	MI	PE to BO
	Metabasalt	Grayish Red (5R 4/2)	MI	PE to BO
	Metasedimentary	Dark Greenish Gray (5G 4/1)	MI	PE to BO
Windy Creek	Metasedimentary	Dark Gray (N3)	MA to MI	PE to BO
Butte Creek 1	Chalcedony	Medium Dark Gray (N4)	MI	PE to CO
	Basalt/Metabasalt	Dark Gray (N3)	MA	PE to BO
	Metachert	Light Olive Gray (5Y 6/1)	MI	PE to BO
	Chalcedony	Dark Gray (N3), Moderate Yellowish Brown (10YR 5/4)	MI	PE to BO
Butte Creek 2	Argillite	Dark Gray (N3)	MI	PE to CO
	Chalcedony	Medium Gray (N5)	MI	PE to CO
	Chalcedony	Light Olive Gray (5Y 6/1), Dark Gray (N3)	MI	PE to CO
	Chalcedony	Grayish Black (N2), Light Olive Gray (5Y 6/1)	MI	PE to CO
	Metasedimentary/silicified siltstone	Grayish Black (N2)	MI	PE to CO
	Chalcedony	Light Gray (N7) to Light Olive Gray (5Y 6/1)	MI	PE to CO
	Chalcedony	Light Brownish Gray (5YR 6/1)	MI	PE to CO
Quaternary Gravels	Chalcedony	Medium Dark Gray (N4)	MI	PE to CO
	Quartzite	Pale Yellowish Brown (10YR 6/2)	MI	PE to CO
	Metachalcedony	Medium Dark Gray (N4)	MI	PE to CO
	Metasedimentary	Dark Gray (N3)	MI	PE to CO

[1] MA: macrocrystalline; MI: microcrystalline; CCS: cryptocrystalline.
[2] BO: boulder; CO: cobble; PE: pebble.

Clearwater Mountains

The Clearwater Mountains are broadly composed of two main sequences of metamorphosed bedrock: Late Triassic age low-grade metavolcanic rocks of the Amphitheatre Group, overlain by pre-Upper Jurassic fine-grained sedimentary rock varying in metamorphism from argillite to layered gneiss (Smith 1981). A review of geologic literature suggests several potential sources of knappable lithic raw material in the Clearwater Mountains. Formations the southern portion of the range south of Windy Creek (Figure 23) are broadly composed of metabasalt and metasedimentary rocks of the Amphitheatre Group. The Amphitheatre Group contains subgroups of tuffaceous metasedimentary rocks, cherts, metabasalts and carbonaceous argillites. The most common rock type described in this formation is a grayish-olive and grayish-red metabasalt and basaltic andesite, characterized by generally fine-grained textures (felsitic, aphanitic, and porphyritic), with phenocrysts and recrystallized minerals in the rock matrix.

There are sedimentary and metasedimentary subformations of the Amphitheatre Group that include a pale-olive or greenish-gray tuffaceous argillite, a medium-gray or gray-black fine-grained argillite, a dark carbonaceous argillite and chert formation, and a medium-gray to light-brownish-gray argillaceous limestone. Often these rock types contain recrystallized minerals from weak metamorphism (Mooney 2010; Smith 1981). Additionally, Kachadoorian et al. (1954) describe white to bright red-brown and green chert, interbedded with volcanic rock and argillite, in bedrock formations in-between Raft and Corkscrew creeks.

We conducted lithic raw material survey of three drainages on the southern flank of the Clearwater Mountains: Raft Creek, Waterfall Creek, and Alpine Creek (Figure 23). Our survey focused on sections of these drainages upslope from quaternary moraine deposits related to glaciation of the broader Susitna valley identified in Smith (1981); the material presented here therefore represents material from ground moraine deposits originating from bedrock formations in the upper portion of the drainages. Our survey identified several knappable quality metasedimentary, metavolcanic, and cryptocrystalline silicate lithic raw material types (Table 14). Material textures are typically microcrystalline or macrocrystalline, and package sizes range from pebble to boulder size classes.

The material collected for this lithic raw material survey primarily match published descriptions of rock types found in the Triassic period Amphitheatre Group. Our survey did not find abundant chert lithic raw material in the Raft Creek drainage as described in Kachadoorian et al. (1954), although lightly metamorphosed reddish-brown CCS from Waterfall Creek might be this material. Chert and metachert recovered from this survey area was recovered only in smaller package sizes, although it may occur in larger package sizes higher in elevation. These data indicate that knappable material of usable size is readily available in these drainages, but is sometimes coarser-grained, and of variable texture from nodule to nodule because of the influence of metamorphic processes. Cryptocrystalline rock types tend to occur in smaller package sizes.

In the central portion of the Clearwater Mountains, north of Windy Creek and south of Valdez Creek (Figure 23), potentially knappable toolstone is available in the dominant argillite unit, described as containing fine-grained grayish-black mudstones with subchoncoidal fracture properties. The geologic literature also describes knappable volcanogenic metasedimentary rocks, greenish to gray argillite, black carbonaceous argillite, olive to greenish-gray metatuffs, black and gray banded argillite, and minor quantities of green, white, and black chert, characterized by finely crystallized quartz and impurities of chlorite (Mooney 2010; Smith 1981).

We conducted lithic raw material survey of the Windy Creek drainage (Figure 23). Our survey identified just one type of knappable lithic raw material, a metasedimentary rock with macrocrystalline to microcrystalline texture, available in cobbles in the exposed gravels of the Windy Creek drainage (Table 14). This material may be from Triassic or Jurassic formations described in the geologic literature. We did not locate any chert during our survey. This suggests that lithic raw material resources in this drainage are limited to variable quality metasedimentary rock.

Geologic formations in the northern Clearwater Mountains (north of Valdez Creek) consist a large belt of phyllite, schist, and gneiss metamorphic rock types, and coarse-grained granodiorite and quartz diorite, some of which have been metamorphosed (Smith 1981). We did not conduct lithic raw material survey of the Valdez Creek drainage or northern portion of the Clearwater Mountains, but the geologic literature suggests that this area may not have significant sources of knappable lithic raw material.

Butte Creek Drainage

Butte Creek drains Butte Lake into the Susitna River, and is the primary drainage of the northeastern Talkeetna Mountains in the study area (Figure 23). The rugged mountains south of lower Butte Creek are part of the Amphitheatre Group described in the southern Clearwater Mountains. In this portion of the study area the Amphitheatre Group consists broadly of metavolcanic, coarse-grained intrusive volcanic, as well as fine-grained clastic and carbonate formations. In addition, interbedded shale, siltstone, sandstone, marl, and pebble conglomerate formations also occur. The Kahiltna Formation in the same mountains south of lower Butte Creek contains conglomerate, sandstone, and siltstone formations (O'Neill et al. 2001). Knappable toolstones potentially present in this area include aphanatic gray-olive to gray-green metabasalt and basaltic andesite, dark gray argillite and siltstone, and tan, gray, white, pink, and light-green chert (Smith et al. 1988).

We conducted lithic raw material survey at two locations near lower Butte Creek (Figure 23). Butte Creek 1 represents a small, steep tributary of Butte Creek primarily draining Amphitheatre Group formations described as containing chert and argillite. Butte Creek 2 represents exposed gravels within Butte Creek, representing material from the entire Butte Creek drainage, including material from the Amphitheatre Group and Kahiltna Formation. Our survey identified several knappable quality raw materials at these two locations. At Butte Creek 1, we collected knappable quality chalcedony, basalt (most of which appears to be weakly metamorphosed), and metachert, ranging in texture from microcrystalline to macrocrystalline, and observed in pebble to boulder nodules (Table 14). This material matches the description of rocks found in the Amphitheatre Group formation, but our survey did not collect the diversity of chert types described in geologic literature, only a single type of weakly metamorphosed chert.

At Butte Creek 2, we collected knappable quality argillite and chalcedony (Table 14). This material ranged in texture from microcrystalline to macrocrystalline, and was observed in pebble to boulder nodules in the drainage. These data indicate that knappable material of usable package size is readily available in these drainages, but is sometimes coarser-grained and of variable quality because of the influence of metamorphic processes.

Quaternary Surficial Deposits

Unconsolidated Quaternary surficial deposits related to Wisconsin glaciation of the broader Susitna basin blanket the study area at elevations below 1000 masl, consisting primarily of glacial drift, often reworked and deposited as alluvium along rivers and streams (Smith 1981; Smith et al. 1988; Wahrhaftig 1960, 1965). These deposits were sampled at three locations: a lateral moraine on the southern slope of the Clearwater Mountains nearby Waterfall Creek, and at two locations with exposed late Wisconsin till cobble beds (Figure 23). At these sampling locations we collected knappable quality chalcedony, quartzite, metachalcedony, and metasedimentary lithic raw materials. This material was all microcrystalline texture, and in pebble- to cobble-sized nodules. The quaternary gravels are variable and likely represent material from local sources as well as more distant sources in the Talkeetna Mountains and southern Alaska Range, the sources of Wisconsin glaciers that covered the study area.

In summary, we found relatively abundant amounts of lithic raw material in the study area. For the most part, this material was microcrystalline to macrocrystalline texture, indicating that overall quality of lithic raw material resources was moderate. Lithic raw materials typically came in cobble- to boulder-sized nodules, indicating that lithic raw material package size was suitable for knapping. The majority of lithic raw material appears to be from the Amphitheatre Group formation that comprises a significant portion of the southern Clearwater Mountains and northeastern Talkeetna Mountains in the study area. The Amphitheatre Group represents a lightly to heavily metamorphosed formation along the Talkeetna Fault, and the knappable lithic raw material presumably related to this formation typically show indications of having undergone weak metamorphism.

Several additional knappable raw materials collected in the study area appear to have been affected by weak metamorphism, likely also a result of proximity to the Talkeetna Fault. As a result, much of the knappable-quality raw material in the study area is of variable quality from one nodule to the next and from one location to the other. Despite several geologic reference sources identifying various cherts as occurring in geologic formations in the study area, our survey found little evidence for abundant chert lithic raw material resources. This apparent disparity may be explained by geologic investigators subsuming the readily available chalcedony in the study area into the broader category of chert. The minor amounts of chert we collected were typically poorer quality as a result of weak metamorphism.

Lithic Assemblages

For a detailed description of the setting, geoarchaeological contexts, and dating for the following sites, see Chapter III. Some of the lithic assemblages from components presented below are very small, and as such provide limited or potentially misleading information about the technological activities represented in the respective components. To avoid this, technological activities related to the components from Susitna Dune 1 C1 and C2, West Fork Susitna 1 C1, Susitna Dune 4 C2, and Butte Lake C1 are not discussed in detail in this paper.

There are three goals to this lithic analysis: (1) to present the lithic assemblages from sites in the upper Susitna study area, (2) to interpret technological activities and lithic raw material procurement patterns from each cultural component at each site, and (3) to use these data to assess settlement organization and landscape use in the upper Susitna basin throughout the Holocene.

Susitna Dune 1 (HEA-454)

There are three components represented at Susitna Dune 1. Component 3 (C3) consists of 209 lithics and approximately 316 fragmented faunal remains recovered from a late Holocene (LH) context (post-dating deposition of the Devil tephra at 1500-1300 cal BP), component 2 (C2) consists of 10 lithics in a MH context (7788-7627 cal BP), and component 1 (C1) consists of four flakes and more than 1490 highly fragmented faunal remains, including highly degraded maxilla and tooth enamel fragments of a large Cervidae, probably wapiti (*Cervus canadensis*) or caribou (*Rangifer tarandus*), in an EH context (11,170-10,770 cal BP). The lithic assemblages from C1 and C2 are small (Table 15), and are not discussed in detail here.

Component 3 lithic assemblage. The lithic assemblage from Susitna Dune 1 C3 consists of 207 debitage and two tools. There are eight classes of lithic raw material; the assemblage is primarily made on chalcedony and basalt, with lesser amounts of andesite and obsidian, and minor amounts of rhyolite, argillite, chert, quartz, and granite (Table 15). The C3 debitage assemblage is dominated by retouch chips, with lesser amounts of retouch chip fragments, flake fragments, biface thinning flakes, and core-reduction flakes (Table 16).

Debitage in the C3 assemblage is predominantly very small, with some small-sized and a single piece of medium-size debitage (Figure 24). Platform types for all proximal flakes in the C3 assemblage are distributed between complex, crushed, and smooth, with a minor amount of lipped platforms (Figure 25). Platform types on very small proximal flakes are mostly smooth and crushed, with slightly less complex types; platform types on small proximal flakes are predominantly complex, with lesser amounts of crushed, and few smooth platform types. The single cortical platform in the C3 assemblage is on a medium size obsidian proximal flake (Figure 26).

There are two tools in the C3 assemblage, one complete retouched argillite biface-thinning flake with unifacial non-invasive use-wear retouch, and one granite pebble retoucher that is roughly oval-shaped with battering on both rounded ends. The single retouched flake was retouched on 30% of available edge units (Table 17), and has a retouch index score of 0.10 (Table 18). There are no cores in the C3 assemblage.

Lithic raw material procurement. More than half (59.3%) of the lithics in the C3 assemblage are made on lithic raw material types collected during our raw material survey of the study area (Table 15). There is variety in some of the raw material classes, including eight types of chalcedony, five types of rhyolite,

Table 15. Susitna Dune 1 (HEA-454) lithic raw material types by component.

	Component 1				Component 2				Component 3			
Raw material	**Debitage** *n (%)*	**Toolss** *n (%)*	**Total** *n (%)*	**Local** *%*	**Debitage** *n (%)*	**Tools** *n (%)*	**Total** *n (%)*	**Local** *%*	**Debitage** *n (%)*	**Tools** *n (%)*	**Total** *n (%)*	**Local** *%*
Chert	-	-	-	-	-	-	-	-	3 (1.4)	-	3 (1.4)	66.7
Obsidian	-	-	-	-	-	-	-	-	21 (10.1)	-	21 (10.0)	0
Basalt	-	-	-	-	-	-	-	-	52 (25.1)	-	52 (24.9)	100
Rhyolite	-	-	-	-	-	-	-	-	12 (5.8)	-	12 (5.7)	0
Chalcedony	1 (25.0)	-	1 (25.0)	100	9 (90.0)	-	9 (90.0)	100	77 (37.2)	-	77 (36.8)	79.2
Argillite	3 (75.0)	-	3 (75.0)	100	1 (10.0)	-	1 (10.0)	100	7 (3.4)	1 (50.0)	8 (3.8)	100
Quartz	-	-	-	-	-	-	-	-	2 (1.0)	-	2 (1.0)	0
Andesite	-	-	-	-	-	-	-	-	33 (15.9)	-	33 (15.8)	0
Granite	-	-	-	-	-	-	-	-	-	1 (50.0)	1 (0.5)	100
Total	4	-	4	100	10	-	10	100	207	2	209	59.3

Table 16. Artifact frequencies by lithic raw material type for Susitna Dune 1 C3.

Artifact type	Chert n (%)	Obsidian n (%)	Basalt n (%)	Rhyolite n (%)	Chalcedony n (%)	Argillite n (%)	Quartz n (%)	Andesite n (%)	Granite n (%)	Total n (%)
Flake fragment	-	2 (9.5)	14 (26.9)	1 (8.3)	8 (10.4)	2 (28.6)	-	10 (30.3)	-	37 (17.9)
Flake	-	3 (14.3)	3 (5.8)	-	3 (3.9)	1 (14.3)	-	2 (6.1)	-	12 (5.8)
Retouch chip fragment	-	2 (9.5)	12 (23.1)	3 (25.0)	22 (28.6)	2 (28.6)	1 (50.0)	6 (18.2)	-	48 (23.2)
Retouch chip	2 (66.7)	11 (52.4)	16 (30.8)	6 (50.0)	38 (49.4)	2 (28.6)	1 (50.0)	12 (36.4)	-	88 (42.5)
Biface thinning flake	1 (33.3)	3 (14.3)	7 (13.5)	2 (16.7)	6 (7.8)	-	-	3 (9.1)	-	22 (10.5)
Debitage subtotal	*3*	*21*	*52*	*12*	*77*	*7*	*2*	*33*	-	*207*
Retouched flake	-	-	-	-	-	1	-	-	-	1
Pebble retoucher	-	-	-	-	-	-	-	-	1	1
Tool subtotal	-	-	-	-	-	*1*	-	-	*1*	*2*
Tool:debitage ratio	-	-	-	-	-	0.14	-	-	1	0.01

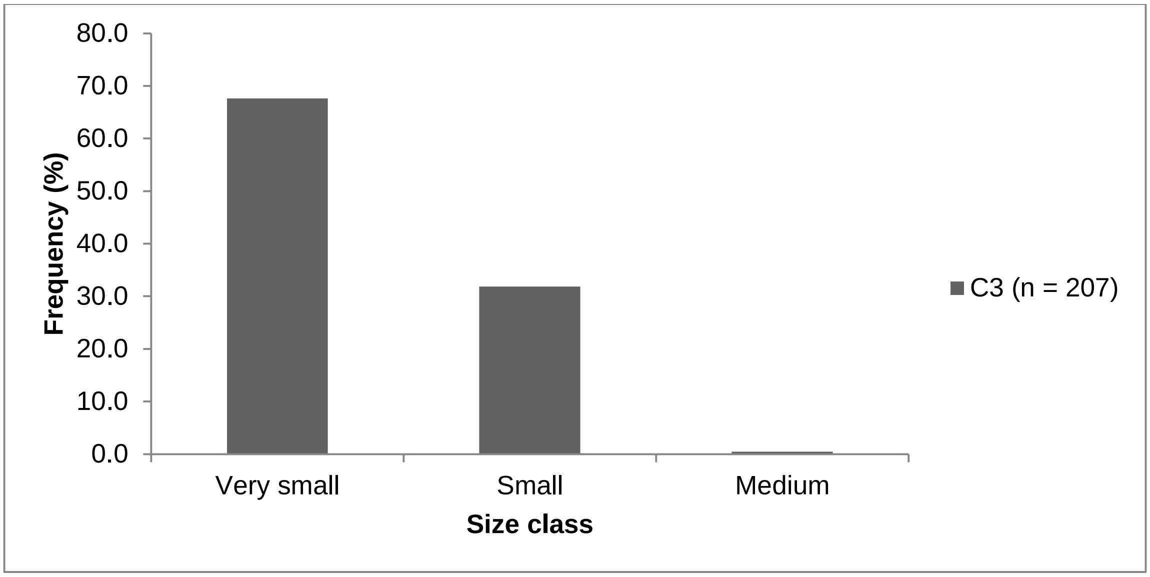

Figure 24. Size class for all debitage in Susitna Dune 1 C3 lithic assemblage.

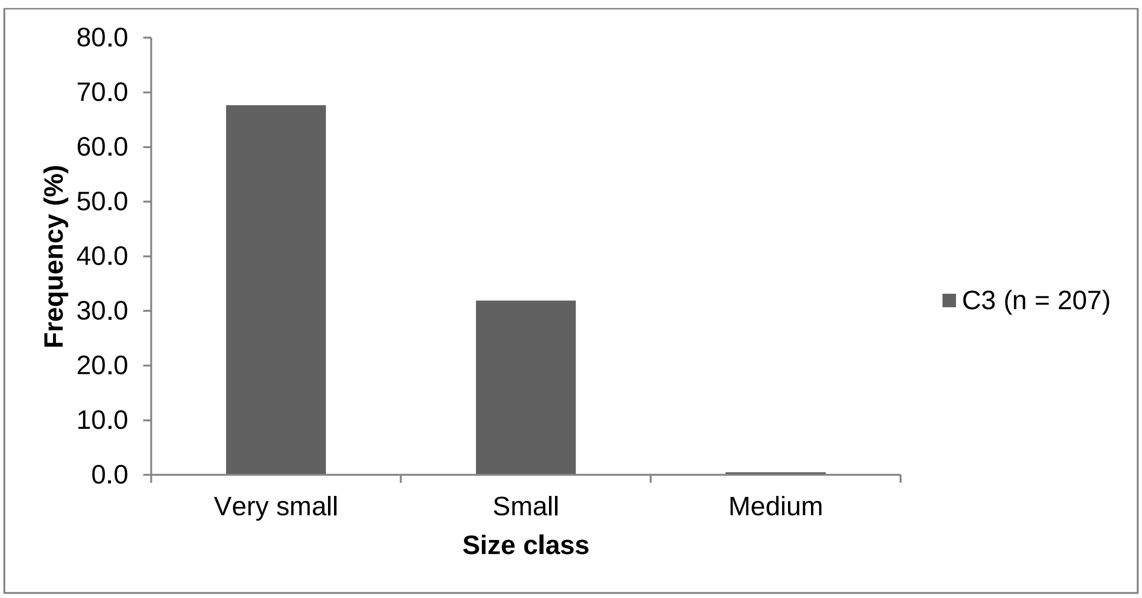

Figure 25. Platform type for proximal debitage in the Susitna Dune 1 C3 lithic assemblage.

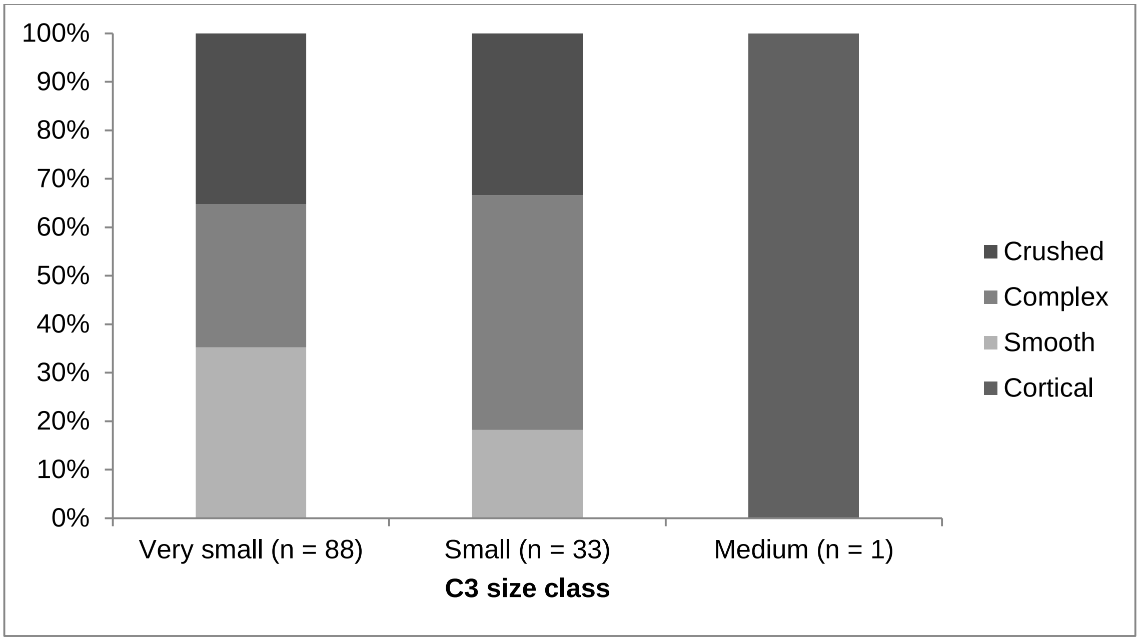

Figure 26. Proximal flake platform type distribution within each debitage size class in the Susitna Dune 1 C3 lithic assemblage.

and two types of chert in the assemblage; the remaining raw materials are represented by a single type each. The most numerous raw material types in the assemblage are a dark gray (N3) basalt (24.9% of assemblage) and a dark gray (N3) and light gray (N7) banded chalcedony (17.2%) that are similar to materials we collected in the Butte Creek drainage approximately 13 km south of the site. The third-most common raw material type is an olive gray (5Y 4/1) andesite that we did not find during our raw material survey.

There are 21 obsidian artifacts in the assemblage, but only one was of suitable size for geochemical characterization, the obsidian flake with a cortical platform. PXRF analysis of this artifact indicates it was made on obsidian from the Batza Téna source, ~430 km northwest of the study area (Table 19).

Table 17. Percentage of unifacial tool edge units with retouch for each cultural component.

Raw material class		Susitna Dune 1	Susitna River 3			Alpine Creek 8	Butte Creek 1	Windy Creek 1	Susitna Dune 4	Ratekin	Butte Lake	
		C3 (n=1)	C1 (n=27)	C2 (n=50)	C3 (n=21)	C1 (n=7)	C1 (n=14)	C1 (n=4)	C3 (n=8)	C1 (n=54)	C1 (n=2)	C2 (n=27)
Chert	Used	3	100	48	13	4	11	-	11	166	9	39
	Available	10	190	88	17	4	13	-	45	188	17	59
	%	*30*	*52.6*	*54.5*	*76.5*	*100*	*84.6*	-	*24.4*	*88.3*	*52.9*	*66.1*
Obsidian	Used	-	-	3	-	-	4	-	-	7	-	5
	Available	-	-	8	-	-	8	-	-	10	-	8
	%	-	-	*37.5*	-	-	*50.0*	-	-	*70*	-	*62.5*
Basalt	Used	-	-	37	20	-	14	-	-	82	-	33
	Available	-	-	71	42	-	24	-	-	94	-	34
	%	-	-	*52.1*	*47.6*	-	*58.3*	-	-	*87.2*	-	*97.1*
Rhyolite	Used	-	-	27	11	-	11	-	6	98	-	-
	Available	-	-	34	23	-	16	-	8	123	-	-
	%	-	-	*79.4*	*47.8*	-	*68.8*	-	*75.0*	*79.7*	-	-
Quartzite	Used	-	-		-	-	-	-	-	10	-	6
	Available	-	-		-	-	-	-	-	10	-	10
	%	-	-		-	-	-	-	-	*100*	-	*60.0*
Chalcedony	Used	-	8	84	38	-	22	7	13	67	-	69
	Available	-	20	192	68	-	43	10	17	67	-	98
	%	-	*40.0*	*43.8*	*55.9*	-	*51.2*	*70.0*	*76.5*	*100*	-	*70.4*
Argillite	Used	-	-	13	-	28	-	16	-	18	-	-
	Available	-	-	20	-	52	-	27	-	19	-	-
	%	-	-	*65.0*	-	*53.8*	-	*59.3*	-	*94.7*	-	-
Meta-sedimentary	Used	-	-	6	-	-	-	-	-	-		-
	Available	-	-	10	-	-	-	-	-	-	-	-
	%	-	-	*60.0*	-	-	-	-	-	-	-	-
Total	Used	3	108	218	82	32	62	23	30	448	9	152
	Available	10	210	423	150	56	104	37	70	511	17	209
	%	*30*	*51.4*	*51.5*	*54.7*	*57.1*	*59.6*	*62.2*	*42.9*	*87.7*	*52.9*	*72.7*

Table 18. Retouch index for unifacial tools for each raw material type from upper Susitna assemblages.

Lithic raw material class		Susitna Dune 1	Susitna River 3			Alpine Creek 8	Butte Creek 1	Windy Creek 1	Susitna Dune 4	Ratekin	Butte Lake	
		C3	C1	C2	C3	C1	C1	C1	C3	C1	C1	C2
Chert	n	-	16	9	2	1	2	-	5	20	2	8
	Mean RI	-	0.54	0.54	0.71	0.57	0.70	-	0.11	0.67	0.48	0.46
	σ	-	0.52	0.54	0.07	-	0.30	-	0.05	0.21	0.44	0.28
Obsidian	n	-	-	1	-	-	1	-	-	1	-	1
	Mean RI	-	-	0.30	-	-	0.09	-	-	0.29	-	0.29
	σ	-	-	-	-	-	-	-	-	-	-	-
Basalt	n	-	-	9	5	-	3	-	-	8	-	4
	Mean RI	-	-	0.40	0.53	-	0.15	-	-	0.67	-	0.56
	σ	-	-	0.32	0.71	-	0.11	-	-	0.25	-	0.31
Rhyolite	n	-	-	4	3	-	3	-	1	13	-	1
	Mean RI	-	-	0.33	0.25	-	0.53	-	1.00	0.73	-	0.33
	σ	-	-	0.23	0.10	-	0.27	-	-	0.23	-	-
Quartzite	n	-	-	-	-	-	-	-	-	1	-	-
	Mean RI	-	-	-	-	-	-	-	-	0.57	-	-
	σ	-	-	-	-	-	-	-	-	-	-	-
Chalcedony	n	-	2	21	7	-	4	1	2	7	-	10
	Mean RI	-	0.27	0.31	0.22	-	0.37	0.10	0.41	0.77	-	0.54
	σ	-	0.28	0.23	0.23	-	0.23	-	0.02	0.18	-	0.26
Argillite	n	1	-	1	-	6	-	3	-	1	-	-
	Mean RI	0.10	-	0.04	-	0.14	-	0.37	-	0.36	-	-
	σ	-			-	0.12	-	0.47	-	-	-	-
Total	n	1	18	46	17	7	13	4	8	50	2	24
	Mean RI	0.10	0.51	0.37	0.37	0.20	0.40	0.30	0.25	0.69	0.48	0.50
	σ	-	0.50	0.33	0.43	0.19	0.30	0.41	0.32	0.22	0.44	0.26

Table 19. PXRF data for obsidian artifacts from the upper Susitna study area.

Site name	AOD number	Catalog number	Cultural component	Source name	Source group	Source distance from site
Susitna Dune 1 (HEA-454)	AOD-12211	UA2010-249-005	C3	Batza Téna	B	430 km NW
Susitna River 3 (HEA-455)	AOD-12212	UA2012-200-001	C2	Wiki Peak	A	350 km SE
	AOD-12214	UA2012-200-002	C2	Wiki Peak	A	350 km SE
Butte Creek 1 (HEA-499)	AOD-12213	UA2012-204-001	C1	Batza Téna	B	435 km NW
	AOD-12608	UA2012-204-0039	C1	A prime (unknown source)	A’	Unknown
	AOD-12609	UA2012-204-0018	C1	A prime (unknown source)	A’	Unknown
Ratekin (HEA-187)	AOD-12258	0742-027	C1	Wiki Peak	A	340 km SE
	AOD-12259	0742-121	C1	Wiki Peak	A	340 km SE
	AOD-12260	0742-272	C1	Batza Téna	B	430 km NW
	AOD-12262	0742-157	C1	Batza Téna	B	430 km NW
Butte Lake (HEA-189)	AOD-12263	UA84-147-143A	C2	Wiki Peak	A	360 km SE
	AOD-12266	UA84-147-186	C2	Wiki Peak	A	360 km SE
	AOD-12267	UA84-147-189A	C2	Wiki Peak	A	360 km SE

Note: PXRF analyses done on Bruker Tracer III-V no. 510 at the University of Alaska Museum of the North, Fairbanks, Alaska.

Two artifacts in the assemblage bear cortex: the pebble retoucher tool has secondary cortex, and the obsidian flake has a secondary cortical platform. The granite pebble utilized as a retoucher could have been procured nearby the site from glacial drift gravels available along dune slopes. Despite the cortical surface, PXRF analysis indicates that the obsidian flake does not represent a locally available raw material.

The chalcedony, basalt, and argillite in the lithic assemblage were likely procured within the study area. The high number of chalcedony raw material types supports local procurement of chalcedony. There are just three chert debitage pieces in the assemblage, and two of these match material we collected in our survey, so this may represent local raw material, but perhaps the small package size issues discussed above prevented this material from being well-represented in the assemblage. The rhyolite and andesite in the assemblage are non-local, but given the amount of andesite in the assemblage, and the diversity in rhyolite types, these raw materials may have been transported to the site from just outside of the study area. While only one of the obsidian artifacts has been sourced, all of this material likely represents long-distance transport of lithic raw materials. Nonetheless, lithic raw material procurement during the C3 occupation of the site focused primarily on locally available lithic sources, with evidence for moderate non-local procurement and a minor amount of long-distance procurement.

Primary reduction. Primary reduction was a minor component of lithic technological activities occurring at the site (23.7% of debitage assemblage). This is supported by the lack of cortical spalls, the low frequency of flake fragments and core-reduction flakes, the low frequency of large and medium debitage, and the low frequency of smooth platforms on small and medium debitage. There are no statistically significant differences in proportions of debitage representing primary and secondary reduction in each raw material type ($\chi^2 = 13.578$, $df = 7$, $p < 0.0592$), but the chi square test results are suspect because 20% of expected counts are less than 5 due to small sample sizes. The high frequency of basalt and andesite flake fragments in the assemblage likely represent informal core reduction for these materials. One piece of debitage in the assemblage bears cortex, the obsidian core-reduction flake with the cortical platform.

There are no cores in the C3 assemblage with which to characterize formality of core production. The retouched flake is made on a biface thinning flake blank, suggesting that it came from a formally prepared argillite bifacial core or tool. The biface thinning flake tool blank could indicate that an argillite bifacial core was reduced onsite, but there are no other argillite biface thinning flakes, so this artifact may have been carried onsite as a tool blank or retouched flake. There is no evidence for bipolar knapping or scavenging in the assemblage. These data suggest that little primary reduction occurred during the time of C3 at Susitna Dune 1, and what little did occur was mostly informal.

Secondary reduction. Secondary reduction was a significant component of lithic technological activities occurring at Susitna Dune 1 (76.3% of debitage assemblage). This is supported by the high frequency of retouch chips and fragments and biface thinning flakes, the high frequency of very small and small debitage, the high frequency of smooth platforms on very small debitage, and the high frequency of complex platforms on small debitage. A moderate focus on biface production is supported by the frequency of bifacial thinning flakes and small proximal flakes with complex platforms. Bifacial and unifacial tool maintenance is supported by the frequency of retouch chip and fragments and the frequency of smooth and complex platform types in the very small debitage size class.

The only tool from the C3 assemblage is a retouched flake. Retouched edge unit and retouch index scores indicate that this informal tool type was minimally utilized and discarded with most of its use-life remaining. While there is evidence for biface production and tool maintenance at the site, there are no bifacial tools in the C3 assemblage. This suggests that the bifacial and unifacial tools may have been carried on to the site, maintained at the site, and then carried away with the site's LH occupants. This is supported by the relatively high argillite tool-to-debitage ratio (0.14). These data suggest that lithic activities at the site focused on secondary reduction and maintenance of tools, including biface production and bifacial and unifacial tool maintenance. Tool manufacture is difficult to discern with the small sample size, but appears to be informal, and the single tool was not maintained.

Susitna River 3 (HEA-455)

There are three components represented at Susitna River 3. Component 1 (C1) consists of 706 lithics and 5 highly fragmented faunal remains recovered from an EH context (10,690-10,300 cal BP), component 2 (C2) consists of consists of approximately 600 highly fragmented faunal remains (Mueller 2015) and 3433 lithics primarily recovered from a charcoal-rich paleosol in a MH context (5711-3984 cal BP), and Component 3 (C3) consists of approximately 160 highly fragmented faunal remains and 1456 lithics recovered from a LH context (2682-2329 cal BP).

Susitna River 3 component 1 lithic assemblage. The lithic assemblage from C1 consists of 673 debitage and 33 tools. There are five classes of lithic raw material in the assemblage. The assemblage is dominated by chert, with lesser amounts of chalcedony, and minor amounts of basalt, rhyolite, and argillite (Table 20). The C1 debitage assemblage consists primarily of retouch chip fragments, retouch chips, and flake fragments, with lesser amounts of biface thinning flakes, core reduction flakes, and burin spalls, and few primary cortical spalls, secondary cortical spalls, and cortical spall fragments (Table 21).

Debitage in the C1 assemblage is predominantly very small, with lesser amounts of small debitage, and very few medium debitage (Figure 27). Platform types for all proximal flakes in the C1 assemblage are primarily smooth and complex, with lesser amounts of crushed platforms and very few lipped platforms (Figure 28). Platform types on very small proximal flakes are predominantly smooth, with lesser amounts of complex and crushed types, and very few lipped. Platform types on small proximal flakes are predominantly complex, with lesser amounts of crushed and smooth types, and very few lipped platforms. The single medium proximal flake has a crushed platform (Figure 29).

Table 20. Susitna River 3 (HEA-455) lithic raw material types by component.

Raw Material	Component 1				Component 2				Component 3			
	Debitage	Tools	Total	Local	Debitage	Tools	Total	Local	Debitage	Tools	Total	Local
	n (%)	*n (%)*	*n (%)*	*%*	*n (%)*	*n (%)*	*n (%)*	*%*	*n (%)*	*n (%)*	*n (%)*	*%*
Chert	388 (57.7)	31 (93.9)	419 (59.4)	0	177 (5.3)	15 (22.4)	192 (5.6)	3.1	42 (2.9)	2 (7.4)	44 (3.0)	13.6
Obsidian	-	-	-	-	8 (0.2)	1 (1.5)	9 (0.3)	0	5 (0.3)	-	5 (0.3)	0
Basalt	37 (5.5)	-	37 (5.2)	100	991 (29.4)	9 (13.4)	1000 (29.1)	99.2	466 (32.6)	9 (33.3)	475 (32.6)	100
Rhyolite	21 (3.1)	-	21 (3.0)	0	849 (25.2)	8 (11.9)	857 (25.0)	0	197 (13.8)	5 (18.5)	202 (13.9)	0
Chalcedony	222 (33.0)	2 (6.1)	224 (31.7)	93.3	1225 (36.4)	29 (43.3)	1254 (36.5)	79.5	702 (49.1)	11 (40.7)	713 (49.0)	83.6
Argillite	5 (0.7)	-	5 (0.7)	100	35 (1.0)	2 (3.0)	37 (1.1)	100	2 (0.1)	-	2 (0.1)	100
Quartz	-	-	-	-	-	-	-	-	1 (0.1)	-	1 (0.1)	0
Andesite	-	-	-	-	77 (2.3)	-	77 (2.2)	-	13 (0.9)	-	13 (0.9)	0
Meta-sedimentary	-	-	-	-	1 (0.0)	2 (3.0)	3 (0.1)	100	1 (0.1)	-	1 (0.1)	100
Meta-volcanic	-	-	-	-	3 (0.1)	1 (1.5)	4 (0.1)	25.0	-	-	-	-
Total	673	33	706	35.6	3366	67	3433	59.3	1429	27	1456	74.2

Table 21. Artifact frequencies by toolstone for Susitna River 3 C1.

Artifact type	Chert n (%)	Basalt n (%)	Rhyolite n (%)	Chalcedony n (%)	Argillite n (%)	Total n (%)
Flake fragment	51 (13.1)	8 (21.6)	6 (28.6)	64 (28.9)	2 (40)	130 (19.3)
Flake	20 (5.2)	6 (16.2)	4 (19.0)	22 (9.9)	2 (40)	54 (8.0)
Cortical spall fragment	-	-	-	-	-	1 (0.1)
Primary cortical spall	-	-	-	1 (0.5)	-	1 (0.1)
Secondary cortical spall	-	-	-	1 (0.5)	-	1 (0.1)
Retouch chip fragment	158 (40.7)	10 (27.0)	6 (28.6)	61 (27.5)	-	235 (35.0)
Retouch chip	115 (29.6)	6 (16.2)	4 (19.0)	48 (21.6)	1 (20)	174 (25.9)
Biface thinning flake	28 (7.2)	7 (18.9)	1 (4.8)	25 (11.3)	-	61 (9.1)
Burin spall	15 (4.1)	-	-	-	-	15 (2.2)
Debitage subtotal	*388*	*37*	*21*	*222*	*5*	*673*
Retouched flake fragment	9 (29.0)	-	-	-	-	9 (27.3)
Retouched flake	3 (9.7)	-	-	2 (100)	-	5 (15.1)
Retouched microblade fragment	1 (3.2)	-	-	-	-	1 (3.0)
Retouched bladelet	1 (3.2)	-	-	-	-	1 (3.0)
Retouched bladelet fragment	2 (6.5)	-	-	-	-	2 (6.1)
Retouched burin spall	2 (6.5)	-	-	-	-	2 (6.1)
Retouched burin spall fragment	6 (19.4)	-	-	-	-	6 (18.2)
End scraper on flake fragment	1 (3.2)	-	-	-	-	1 (3.0)
Burin fragment	1 (3.2)	-	-	-	-	1 (3.0)
Burin on snap	2 (6.5)	-	-	-	-	2 (6.1)
Burin on snap fragment	1 (3.2)	-	-	-	-	1 (3.0)
Angle burin fragment	1 (3.2)	-	-	-	-	1 (3.0)
Burin on notch fragment	1 (3.2)	-	-	-	-	1 (3.00
Tool subtotal	*31*	-	-	*2*	-	*33*
Formal:informal	7:24 0.3	-	-	0:2 0	-	7:26 0.3
Complete:broken	9:22 0.4	-	-	2:0 -	-	11:22 0.5
Mean complete tool weight (g)	0.4	-	-	0.4	-	0.4
Tool:debitage	0.08	-	-	0.01	-	0.05

Figure 27. Size class for all debitage in Susitna River 3 lithic assemblages.

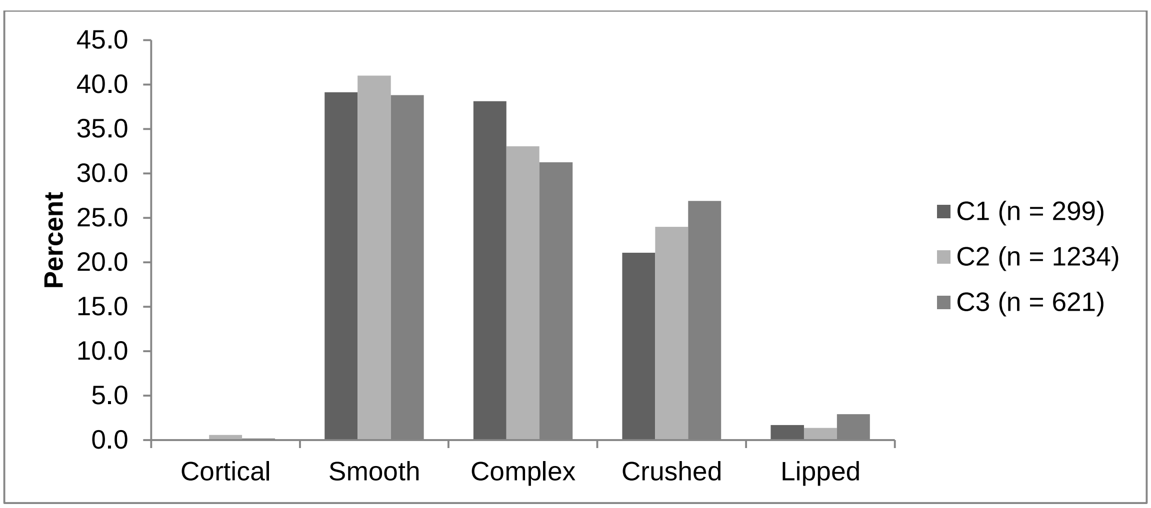

Figure 28. Platform type for all proximal flakes in Susitna River 3 assemblage.

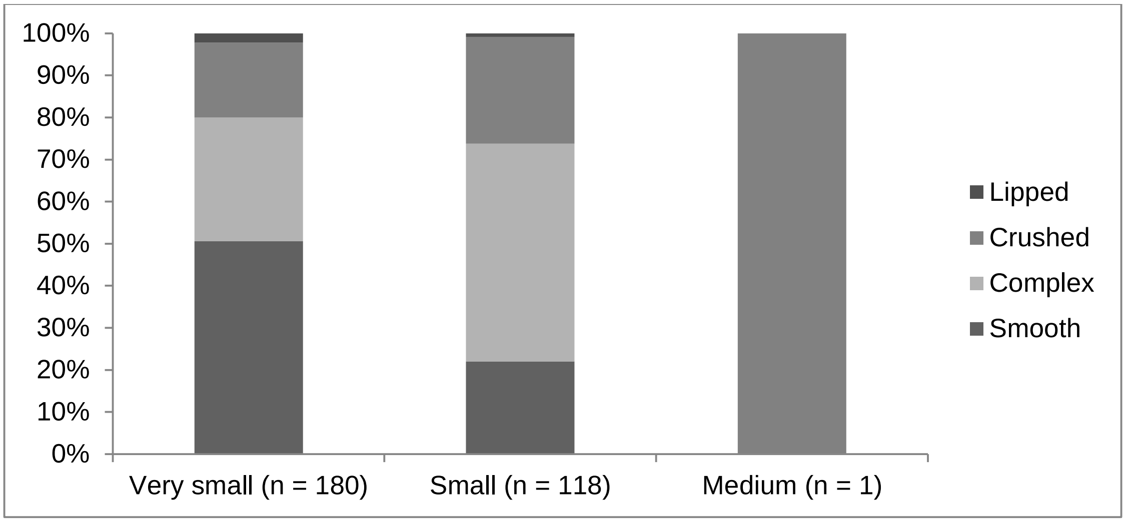

Figure 29. Platform types for proximal flakes within each size class for Susitna River 3 C1.

There are 33 tools in the C1 assemblage (Figure 30), primarily retouched burin spalls and flakes (78.9% of tool assemblage), but also burins (18.1% of tool assemblage) and a very small end scraper made on a bladelet tool blank (Table 21). The most common tool blank is flake, with lesser amounts of burin spall and bladelet blanks, and few microblade and biface thinning flake blanks (Figure 31). The majority of tools in the assemblage are broken, and complete tools have a low mean weight (Table 21). The majority of tools are made on chert (Table 21). None of the tools in the C1 assemblage bear cortex. Chert tools in the C1 assemblage were retouched on 52.6% of available margins, while chalcedony tools were retouched on 40% of available margins (Table 17). Similarly, chert tools have a higher retouch index (0.54) than chalcedony tools (0.28) (Table 18). There are no cores in the C1 assemblage.

Figure 30. Lithic tools from Susitna River 3 C1 assemblage. Top row: burin, endscraper, burin, burin; second row from top: burin spalls; third row from top: retouched bladelets; bottom row: retouched flakes.

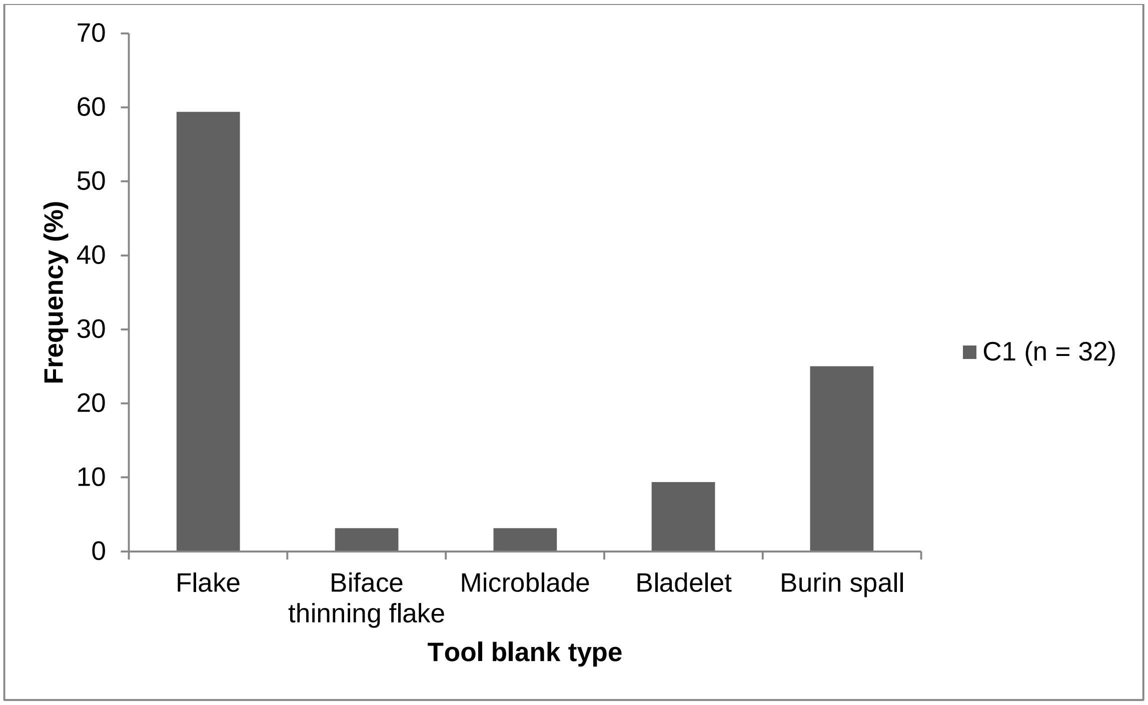

Figure 31. Tool blank type for tools in Susitna River 3 C1.

Lithic raw material procurement. Only 35.6% of the lithics in the C1 assemblage are made on lithic raw material types collected during our raw material survey of the study area (Table 20). There is little diversity within the C1 raw material classes: there are nine types of chalcedony, three types of chert and rhyolite, two types of argillite, and one type of basalt. The assemblage is dominated by one type of chert in particular, a fine-grained grayish orange (10YR 7/4) to moderate yellowish brown (10YR 5/4) material that was occasionally banded with very pale orange (10YR 8/2). The majority of the lithics in the C1 assemblage (53.7%) is made on this material, followed by a medium light gray (N6) to medium gray (N5) chalcedony with black (N1) speckles (28.2% of assemblage). Tools in the assemblage are made primarily on a distinct, fine-grained grayish red (5R 4/2, 10R 4/2) material (n=13, 52%), as well as the grayish orange chert (n=10, 40%). Neither of the chert types described here were collected during our raw material survey of the study area, but we did collect samples of the gray chalcedony in the Butte Creek drainage approximately 13 km to the south of the site. Local procurement of chalcedony is supported by the presence of cortex on two chalcedony flakes; this cortex has the appearance of being from a primary geologic source.

The chert lithic raw material that dominates the C1 assemblage was likely transported to the study area from a more distant source, as was the rhyolite. The chalcedony, argillite, and basalt in the assemblage were likely procured locally. Lithic raw material procurement during the C1 occupation of the site focused primarily on non-local, high-quality cherts, with lithic raw materials supplemented by locally-available chalcedony, basalt, and argillite, most of which was available within 13 km of the site.

Primary reduction. Primary reduction was a minor component of lithic technological activities occurring at Susitna River 3 C1 (27.8% of debitage assemblage). This is supported by the low frequency of core-reduction flakes and cortical spalls in the debitage assemblage, the low frequency of large and medium debitage, and the low frequency of smooth platforms on small and medium debitage. The lack of cortical debitage for most lithic raw material classes suggests that raw materials were initially reduced elsewhere. The exception to this is chalcedony, which is locally available and appears to have undergone some initial reduction onsite. There are higher than expected amounts of argillite, basalt, chalcedony, and rhyolite primary reduction debitage in the assemblage, suggesting what little primary reduction there was focused on these materials; differences in the proportion of these materials is significant ($\chi^2 = 45.463$, $df = 4$, $p < .0001$).

The high frequency of chalcedony flake fragments supports chalcedony core production and reduction, and suggests that chalcedony was reduced informally. In addition, the frequency of chert flake fragments could also represent informal chert core production and reduction, but flake fragments represent a small percentage of chert debitage at the site, so this was a minor component of chert reduction. Mean argillite debitage weight (Wilcoxon each pair: $z = 3.83831$, $p = 0.0001$), chalcedony debitage weight ($z = 8.52888$, $p < .0001$), basalt debitage weight ($z = 6.75048$, $p < .0001$) and rhyolite debitage weight ($z = 2.23866$, $p = 0.252$) are significantly higher that mean chert debitage weight. This supports more initial reduction of locally available argillite, chalcedony, and basalt, and also non-local rhyolite. Primary reduction of non-local rhyolite could represent informal rhyolite cores entering the site.

There are no cores in the C1 assemblage that can be used to characterize formality of core production and reduction. Tools are primarily made on informal flake blanks, but there is evidence for formal core reduction in bladelet, microblade, and biface thinning flake tool blanks. There is no evidence for bipolar knapping or scavenging in the assemblage. These data suggest that primary reduction was a minor component of lithic reduction activities, but focused on informal reduction of locally available raw material, with some formal reduction of non-local cherts.

Secondary reduction. Secondary reduction was a significant component of lithic technological activities during the C1 occupation (72.2% of debitage assemblage), supported by the frequency of small and very small debitage. There are higher than expected amounts of chert secondary reduction debitage in the assemblage, suggesting secondary reduction focused on chert; differences in the proportion of reduction for raw materials are significant ($\chi^2 = 45.463$, $df = 4$, $p < .0001$). Secondary reduction focused on biface production, supported by the high frequency of complex platforms on small debitage, despite the relatively small number of clear biface thinning flakes. The high frequency of retouch chips supports a focus on tool maintenance, the high frequency of smooth platforms on very small debitage supports a focus on unifacial tool maintenance, but the frequency of complex platforms on small debitage indicates bifacial tool maintenance also occurred.

Tools in the C1 assemblage are primarily informal tool types, and are lightweight. Most of the tools were made on non-local, high-quality chert. Chert tools exhibit retouch on a moderate percentage of edge units (Table 17), and were discarded with a moderate amount of utility remaining (Table 18). Tools in the assemblage underwent moderate amounts or retouch, with chert tools being retouched on a higher percentage of edge units and discarded with less utility remaining than chalcedony tools. Both chert and chalcedony tools were primarily discarded broken, suggesting conservation of lithic raw material (Table 21). Given the frequency of retouch chips at the site, it is possible that additional formal chert tools (e.g., bifaces) were carried onto the site, resharpened, then carried away, and only more expedient tool types were discarded as they broke. The relatively high chert tool-to-debitage ratio supports chert tools carried onto the site, while chalcedony tools were probably made onsite and then discarded after minimal use.

The number of burin spalls in the assemblage suggests that tool resharpening in the form of burinaton occurred frequently. In several cases chert burin spalls were utilized as tools after removal, suggesting that chert lithic raw material was being used to the last amount of utility. The presence of burins suggests a specialized toolkit focused in working osseous or wood materials. These data suggest that lithic activities during the C1 occupation focused primarily on secondary unifacial tool maintenance, with lesser amounts of biface production. Tool production appears to have focused on informal tool production and maintenance, but informal tools types were also maintained. Chert tools were maintained more than tools made on locally available chalcedony.

Susitna River 3 component 2 lithic assemblage. The lithic assemblage from C2 consists of 3366 debitage and 67 tools. There are nine classes of lithic raw material. The assemblage is primarily chalcedony, basalt, and rhyolite, with significantly lesser amounts of chert, andesite, argillite, obsidian, metavolcanic, and metasedimentary raw material types (Table 20). The C2 debitage assemblage consists primarily of retouch chip fragments, flake fragments, and retouch chips, with lesser amounts of core-reduction flakes and biface thinning flakes, and minor amounts of cortical spall fragments, secondary cortical spalls, primary cortical spalls, microblade fragments, shatter, burin spalls, bladelet fragments, and one unworked gravel that is interpreted to be a manuport. Technical debitage in the C2 assemblage consists of a single microblade core tablet (Table 22).

Debitage in the C2 assemblage is primarily very small and small, with infrequent medium and large debitage (Figure 27). Platform types for all proximal flakes in the C2 assemblage are primarily smooth, with lesser amounts of complex and crushed platforms, and very few lipped platforms (Figure 28). Platform types on very small proximal flakes are primarily smooth, with lesser amounts of complex and crushed types, and very few lipped. Platform types on small flakes are primarily complex, with lesser amounts of smooth and crushed, and minor amounts of cortical and lipped platform types. Platform types on medium proximal debitage are primarily complex, with lesser amounts of crushed and smooth platform types. Platform types on large flakes are smooth and crushed platform types, but represent just three proximal debitage pieces (Figure 32).

There are 67 tools in the C2 assemblage, primarily retouched flakes, bifaces, and scrapers, but also two knives and one burin (Table 22, Figure 33).

Table 22. Artifact frequencies by toolstone for Susitna River 3 C2.

Artifact type	Chert n (%)	Obsidian n (%)	Basalt n (%)	Rhyolite n (%)	Chalcedony n (%)	Argillite n (%)	Andesite n (%)	Metasedimentary n (%)	Metavolcanic n (%)	Total n (%)
Flake fragment	26 (14.7)	-	289 (29.2)	260 (30.6)	298 (24.3)	11 (31.4)	27 (35.1)	-	-	911 (27.1)
Flake	9 (5.1)	2 (25.0)	111 (11.2)	71 (8.4)	125 (10.2)	6 (17.1)	10 (13.0)	1 (100)	1 (33.3)	336 (10.0)
Cortical spall fragment	-	-	11 (1.1)	3 (0.4)	6 (0.5)	-	-	-	-	20 (0.6)
Primary cortical spall	-	-	3 (0.3)	1 (0.1)	1 (0.1)	-	-	-	-	5 (0.1)
Secondary cortical spall	-	-	2 (0.2)	2 (0.2)	3 (0.2)	-	-	-	-	7 (0.2)
Retouch chip fragment	75 (42.4)	2 (25.0)	305 (30.8)	319 (37.6)	466 (38.0)	5 (14.3)	21 (27.3)	-	-	1193 (35.4)
Retouch chip	43 (24.3)	3 (37.5)	189 (19.1)	117 (13.8)	239 (19.5)	8 (22.9)	12 (15.6)	-	1 (33.3)	612 (18.2)
Biface thinning flake	18 (10.2)	1 (12.5)	78 (7.9)	75 (8.8)	83 (6.8)	5 (14.3)	7 (9.1)	-	1 (33.3)	268 (8.0)
Shatter	-	-	2 (0.2)	1 (0.1)	1 (0.1)	-	-	-	-	4 (0.1)
Unworked gravel	-	-	-	-	1 (0.1)	-	-	-	-	1 (0)
Microblade core tab	1 (0.6)	-	-	-	-	-	-	-	-	1 (0)
Bladelet fragment	1 (0.6)	-	1 (0.1)	-	1 (0.1)	-	-	-	-	3 (0.1)
Microblade fragment	4 (2.3)	-	-	-	1 (0.1)	-	-	-	-	5 (0.1)
Debitage subtotal	*177*	*8*	*991*	*849*	*1225*	*35*	*77*	*1*	*3*	*3366*
Hafted bifacial point fragment	1 (6.7)	-	-	3 (37.5)	1 (3.4)	-	-	-	1 (100)	6 (9.0)
Unhafted biface fragment	-	-	-	-	1 (3.4)	-	-	-	-	1 (1.5)
Finished biface fragment	-	-	-	-	2 (6.9)	-	-	-	-	2 (3.0)
Bifacial knife fragment	-	-	-	-	-	-	-	1 (50)	-	1 (1.5)
Retouched flake fragment	5 (33.3)	1 (100)	4 (44.4)	3 (37.5)	14 (48.3)	1 (50)	-	-	-	28 (41.8)
Retouched flake	3 (20.0)	-	4 (44.4)	1 (12.5)	9 (31.0)	-	-	1 (50)	-	18 (26.9)
Retouched burin spall fragment	4 (26.7)	-	-	-	-	-	-	-	-	4 (6.0)
Flake-backed knife	-	-	-	-	-	1 (50)	-	-	-	1 (1.5)
End scraper fragment	-	-	-	-	1 (3.4)	-	-	-	-	1 (1.5)
End scraper on flake	1 (6.7)	-	-	-	1 (3.4)	-	-	-	-	2 (3.0)
Steeply keeled end scraper	-	-	-	1 (12.5)	-	-	-	-	-	1 (1.5)
Single-straight side scraper	-	-	1 (11.1)	-	-	-	-	-	-	1 (1.5)
Angle on platform burin	1 (6.7)	-	-	-	-	-	-	-	-	1 (1.5)
Tool subtotal	*15*	*1*	*9*	*8*	*29*	*2*	-	*2*	*1*	*67*
Formal:informal	3:12	0:1	1:8	4:4	6:23	1:1	-	1:1	1:0	17:50
	0.3	0	0.1	1	0.3	1		1	-	0.3
Complete:	6:9	0:1	5:4	2:6	12:17	1:1	-	1:1	0:1	27:40
broken	0.7	0	1.3	0.3	0.7	1		1	0	0.7
Mean complete tool weight	6.4	-	2.9	8.4	1.8	9.2	-	63.6	-	6.4
Tool:debitage	0.08	0.13	0.01	0.01	0.02	0.06	-	2	0.33	0.02

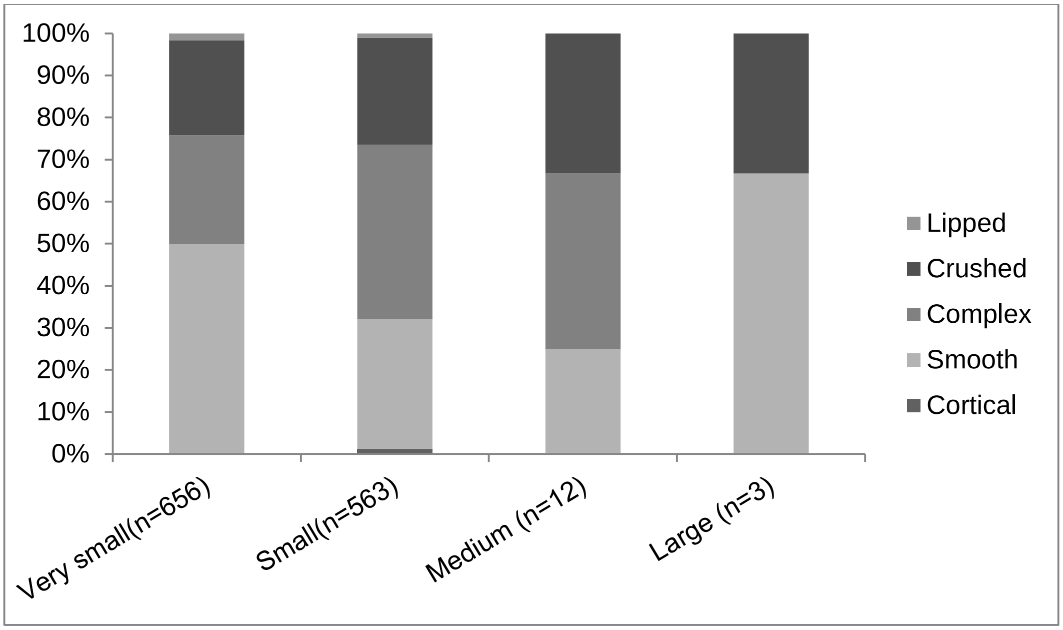

Figure 32. Platform types within each size class for Susitna River 3 C2.

Figure 33. Lithic tools from Susitna River 3 C2 assemblage. Top row: bifaces; middle row: retouched flake, retouched flake, endscraper, retouched flakes; bottom row: endscraper, endscraper, knife.

The most common tool blank type is flake, with lesser amounts of bladelet, biface thinning flake, and biface tool blanks (Figure 34). Tools are primarily informal tool forms, were often discarded in a complete state, and are generally heavy (Table 22). Tools are primarily made on chalcedony, with lesser amounts made on chert, basalt, and rhyolite, and few made on metasedimentary, argillite, obsidian, and metavolcanic lithic raw materials. Three basalt tools in the C2 assemblage bear cortex, two have primary cortex, and one has secondary cortex. In addition, a single rhyolite tool bears primary cortex.

Rhyolite unifacial tools in the C2 assemblage exhibit the most retouched edge units, followed by argillite, metasedimentary, chert, and basalt unifacial tools. Chalcedony and obsidian unfacial tools were retouched on less than half of available margins (Table 17). Chert tools have the highest retouch index, followed by basalt, rhyolite, chalcedony, and obsidian; the single argillite tool has a low retouch index (Table 18). There are no cores in the C2 assemblage.

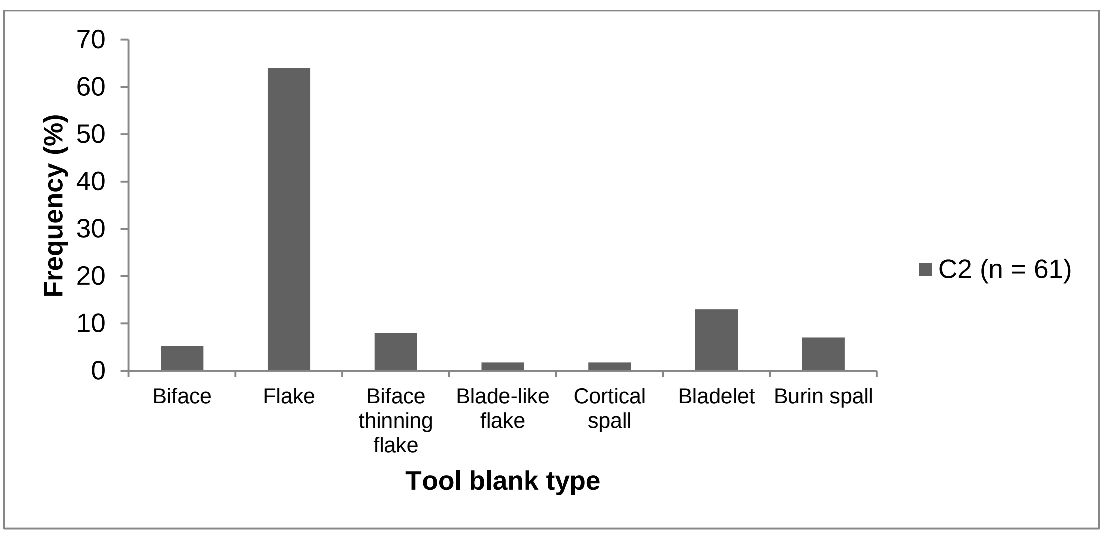

Figure 34. Tool blank type for tools in Susitna River 3 C2.

Lithic raw material procurement. Slightly more than half (59.3%) of the lithics in the C2 assemblage are made on locally available lithic raw materials that were collected during our lithic raw material survey (Table 20). Several of the raw material classes exhibit within-class diversity: there are 19 types of chalcedony, 9 types of chert, 7 types of rhyolite, 4 types of argillite, 2 types of basalt, andesite, and metavolcanic, and one type of obsidian and metasedimentary raw material types in the assemblage. The most common raw material types in the assemblage are a dark gray (N3) basalt (28.9% of the assemblage), and a medium light gray (N6) to medium gray (N5) chalcedony with black (N1) speckles (23.1% of the assemblage). Both of these raw material types were collected in the Butte Creek drainage approximately 13 km south of the site during our raw material survey.

There is also evidence for on-site procurement of lithic raw materials; the metasedimentary rock in the assemblage (represented by one core reduction flake, a retouched flake, and a crudely-worked bifacial knife fragment) represents the naturally occurring bedrock upon which the site is situated on; this material outcrops in many locations on the landform. There are nine obsidian artifacts in the C2 assemblage, but only two were of suitable size for geochemical characterization. PXRF analysis of these two artifacts indicates that these flakes were made on Wiki Peak obsidian, available approximately 350 km southeast of the site (Table 19).

The chalcedony and basalt raw materials that dominate the assemblage were likely procured within the study area; we located these materials during our raw material survey, and there are basalt and chalcedony artifacts that bear cortex in the assemblage. A small amount of the chert in the assemblage matches material collected during our raw material survey, but the majority of this material appears to have been carried into the study area from elsewhere. Also, the rhyolite raw material types present in the assemblage were not located during our survey and likely represent raw material carried into the study area. However, there are rhyolite cortical spalls, and a rhyolite tool with remaining cortex. This suggests that this raw material was carried to the site in unreduced form, and may be available just outside of the study area.

Lithic raw material procurement during the C2 occupation of the site focused primarily on lithic raw materials available in the study area, and in some cases poor quality materials located directly at the site. There is also a significant portion of the assemblage that is made on lithic raw materials not collected during our survey, representing some non-local procurement. In addition, obsidian in the assemblages indicates that some long-distance transport of lithic raw materials occurred, but that this was a minor component of lithic raw material procurement.

Primary reduction. Primary reduction was a minor component of lithic technological activities occurring at the site (38.4% of debitage assemblage). This is supported by the low frequency of core reduction flakes and cortical spalls in the assemblage, the low frequency of large and medium debitage, and the low frequency of smooth platforms on small, medium, and large debitage. The low frequency of cortical debitage (0.9% of debitage assemblage) indicates that most raw materials used at the site were initially reduced elsewhere. There are higher than expected frequencies of andesite, argillite, basalt, and rhyolite primary reduction debitage, suggesting what little primary reduction occurred at the site focused on these materials. The differences in proportions of primary versus secondary debitage for each raw material class was significant ($\chi^2 = 32.933$, $df = 6$, $p < .00001$). Mean debitage weight for chalcedony ($z = 5.41081$, $p < .0001$), basalt ($z = 5.83537$, $p < .0001$), rhyolite ($z = 4.70298$, $p < .0001$), argillite ($z = 5.40418$, $p < .0001$), and andesite ($z = 5.19592$, $p < .0001$) are higher than chert mean debitage weight.

Flake fragments in the assemblage likely represent informal reduction, most commonly of rhyolite, chalcedony, and basalt. There are no cores in the C2 assemblage with which to understand formality of core production and reduction, but the microblade core tablet and microblade and bladelet debitage may indicate that some formal core reduction occurred during this occupation. This is questionable though, as all chert formal core debitage pieces (microblade core tablet, four microblade fragments, and one bladelet) are made on the same fine-grained grayish red (5R 4/2, 10R 4/2) chert common in the C1 assemblage, so this may actually represent material from the underlying component that has been mixed into the overlying component by some post-depositional process, most likely by solifluction evident during excavation of the site. The presence of bladelets on basalt and chalcedony suggests that limited formal reduction may be associated with the C2 occupation as well. Tools are primarily made on informal flake blanks, including cortical spalls and blade-like flakes, but there is evidence for some formal core reduction in bladelet and biface thinning flake tool blanks. Cores were evidentially not discarded onsite during the C2 occupation, at least not in areas excavated to date.

There is evidence for tool recycling in C2. The single chalcedony hafted bifacial point fragment is the end fragment of a biface with flake arris wear suggesting it was hafted and likely broke in the haft; following fracture in the haft it appears the biface was thinned in an attempt to reshape it, but during this process the biface broke on a removal that plunged into the biface. After this, the thin edge of the plunging fracture was utilized as a tool, resulting in bilateral, marginal use-wear. These data suggest that the limited primary reduction at the site was focused on reduction of locally available lithic raw materials, but also on presumed non-local rhyolite. Primary reduction focused on informal core reduction, with some indications of formal core reduction.

Secondary reduction. Secondary reduction comprises 61.6% of the C2 debitage assemblage. There are higher than expected frequencies of chalcedony and chert secondary reduction debitage; the differences in proportions of primary versus secondary debitage for each raw material class is significant ($\chi^2 = 32.933$, $df = 6$, $p < .00001$). This suggests that chert and chalcedony raw material underwent more late-stage reduction than other raw materials. Lithic technological activities during the C2 occupation were primarily focused on bifacial tool production and bifacial and unifacial tool maintenance. Biface thinning flakes comprise just 7.8% of the entire C2 lithic assemblage, but the majority of small and medium proximal flakes have complex platforms, suggesting that these pieces are the result of formal core and tool production and use, and may represent thinning of bifacial tools and/or cores.

The overwhelmingly high frequency of retouch chips and retouch chip fragments and the high frequency of complex and smooth platforms in small-sized debitage supports maintenance of bifacial and unifacial tools as the main reduction activity occurring at the site during the C2 occupation. Flake attribute analysis also supports this inference; most of the debitage in the assemblage is very small or small, suggesting secondary reduction. A focus on secondary reduction is further supported by the low frequency of cortical spalls and core-reduction flakes in the C2 assemblage. Burin spalls in the assemblage suggest that tool resharpening in the form of burinaton also occurred at the site, but was a minor component of secondary reduction activities (but see discussion of burin context above).

Tools in the C2 assemblage are primarily informal tool types, but there are several specialized forms, including several end scraper types and notched hafted biface projectile points. Unifacial tools on all raw material types have relatively moderate percentage of edge units retouched; the exception to this are rhyolite unifacial tools, which have a high percentage of edge units retouched. Similarly, almost all unifacial tools on all raw material types have moderate retouch index scores, the exception being a single argillite unifacial tool with a low retouch index, indicating that it was discarded with most of its utility remaining.

Three of the nine formal tools are made on chert, and three are on rhyolite, suggesting that non-local raw materials may have entered the site in the form of finished formal tools. The relatively high chert and obsidian tool-to-debitage ratio supports these materials entering the site as finished tools, while other raw materials may have been reduced into tools onsite. The metasedimentary and metavolcanic tool-to-debitage ratios are outliers related to small sample sizes. The high percentage of retouched edges on rhyolite tools supports the use of rhyolite to produce formal tools. Four of the hafted bifacial point fragments are notched projectile point fragments and can be assigned to the Northern Archaic tradition (Esdale 2008). Three of the four hafted bifaces are made on rhyolite, and one on chert. In addition, the two rhyolite finished biface fragments in the assemblage represent the very tips of finished bifaces, both with impact damage on their distal most ends, suggesting these are the tips of rhyolite projectile points. Interestingly, both of these tips were recovered in the same hearth feature (Feature 2), and could represent projectile tips broken off in prey and discarded in camp while processing or consuming. These data also support the use of these high quality, non-local raw materials for formal tools, especially notched points.

The chert angle burin, four retouched burin spalls, and seven of the retouched flakes and fragments are made on the same grayish orange (10YR 7/4) to moderate yellowish brown (10YR 5/4) and grayish red (5R 4/2, 10R 4/2) chert common in the underlying C1 assemblage. Given the similarities in technology and raw material with the underlying components, these tools may represent materials mixed into the C2 assemblage by post depositional processes.

Tools appear to have been somewhat frequently discarded in complete form (Table 22). One piece highlights this; the single complete rhyolite retouched flake in the assemblage has a smoothed, worn flake arris and edge wear on the proximal and medial portions of the flake blank, suggesting it was hafted, but has only unifacial, non-invasive use-wear retouch on the distal end, indicating it was only minimally used as a tool. This piece has a retouch index score of 0.18, indicating it was discarded early on in its use-life. These data suggest that lithic technological activities during the C2 occupation of Susitna River 3 focused on secondary production of bifaces, and bifacial and unifacial tool maintenance. Tools were both formal and informal, were commonly discarded complete, and exhibit a broad range of retouch intensity.

Susitna River 3 component 3 lithic assemblage. The lithic assemblage from C3 consists of 1429 debitage and 27 tools. The assemblage has nine raw material classes. The C3 lithic assemblage is dominated by chalcedony and basalt, with lesser amounts of rhyolite and minor amounts of chert, andesite, obsidian, argillite, quartz, and metavolcanic rock (Table 20). The C3 debitage assemblage consists primarily of retouch chip fragments, flake fragments, and retouch chips, with lesser amounts of core reduction flakes and biface thinning flakes, and minor amounts of shatter, secondary cortical spalls, primary cortical spalls, and cortical spall fragments. Technical debitage in C3 consists of one bladelet core-trimming flake (Table 23). Debitage in the C3 assemblage is primarily very small, with some small and few medium size pieces (Figure 27). Platform types for all proximal flakes in the C3 assemblage are primarily smooth, complex, and crushed, with few lipped platforms (Figure 28). Platform types on very small flakes are predominantly smooth, with lesser amounts of crushed, complex, and lipped. Platform types on small and medium proximal flakes are predominantly complex, with lesser amounts of smooth, crushed, and lipped (Figure 35).

There are 27 tools in the C3 assemblage, primarily retouched flakes and fragments (66.6% of tool assemblage), but also including hafted and unhafted bifaces, an early stage biface with a retouched edge indicating use as a tool, an end scraper on flake that was bifacially reworked, and a burin (Figure 36). Tools are primarily made on basalt and chalcedony (74.1% of tool assemblage), but also on rhyolite and chert (Table 23). Two of the tools in the C3 assemblage bear cortex; one chert retouched flake and one basalt end scraper on flake/early

Table 23. Artifact frequencies by toolstone for Susitna River 3 C3.

Artifact type	Chert n (%)	Obsidian n (%)	Basalt n (%)	Rhyolite n (%)	Chalcedony n (%)	Argillite n (%)	Quartz n (%)	Andesite n (%)	Metasedimentary n (%)	Total n (%)
Flake fragment	10 (23.8)	1 (20.0)	123 (26.4)	47 (23.9)	161 (22.9)	-	-	4 (30.8)	-	346 (24.2)
Flake	2 (4.8)	-	63 (13.5)	28 (14.2)	58 (8.3)	-	-	3 (23.1)	-	154 (10.8)
Cortical spall fragment	-	-	2 (0.4)	1 (0.5)	2 (0.3)	-	-	-	1 (100)	6 (0.4)
Primary cortical spall	-	-	3 (0.6)	-	1 (0.1)	-	-	-	-	4 (0.3)
Secondary cortical spall	-	-	2 (0.4)	1 (0.5)	4 (0.6)	-	-	-	-	7 (0.5)
Retouch chip fragment	13 (31.0)	2 (40.0)	131 (28.1)	69 (35.0)	232 (33.0)	-	-	3 (23.1)	-	450 (31.5)
Retouch chip	13 (31.0)	2 (40.0)	97 (20.8)	30 (15.2)	196 (27.9)	-	1 (100)	2 (15.4)	-	341 (31.5)
Biface thinning flake	4 (9.5)	-	44 (9.4)	20 (10.2)	43 (6.1)	2 (100)	-	1 (7.7)	-	114 (8.0)
Shatter	-	-	1 (0.2)	1 (0.5)	4 (0.6)	-	-	-	-	6 (0.4)
Bladelet core trimming flake	-	-	-	-	1 (0.1)	-	-	-	-	1 (0)
Debitage subtotal	*42*	*5*	*466*	*197*	*702*	*2*	*1*	*13*	*1*	*1429*
Hafted bifacial point fragment	-	-	2 (22.2)	1 (20.0)	-	-	-	-	-	3 (11.1)
Hafted bifacial knife fragment	-	-	-	-	1 (9.1)	-	-	-	-	1 (3.7)
Early stage biface/retouched flake fragment	-	-	-	-	1 (9.1)	-	-	-	-	1 (3.7)
Finished biface fragment	-	-	1 (11.1)	1 (20.0)	-	-	-	-	-	2 (7.4)
Retouched flake fragment	1 (50)	-	4 (44.4)	2 (40.0)	6 (54.5)	-	-	-	-	13 (48.1)
Retouched flake	-	-	2 (22.2)	1 (20.0)	2 (18.2)	-	-	-	-	5 (18.5)
End scraper on flake/early stage biface fragment	1 (50)	-	-	-	-	-	-	-	-	1 (3.7)
Burin on snap fragment	-	-	-	-	1 (9.1)	-	-	-	-	1 (3.7)
Tool subtotal	*2*	-	*9*	*5*	*11*	-	-	-	-	*27*
Formal:informal	1:1	-	3:6	2:3	3:8	-	-	-	-	9:18
	1		0.5	0.7	0.4					0.5
Complete:	0:2	-	2:7	1:4	2:9	-	-	-	-	5:22
broken	0		0.3	0.3	0.2					0.3
Mean complete tool weight	-	-	2.9	0.2	0.5	-	-	-	-	1.4
Tool:debitage	0.05	-	0.02	0.03	0.02	-	-	-	-	0.02

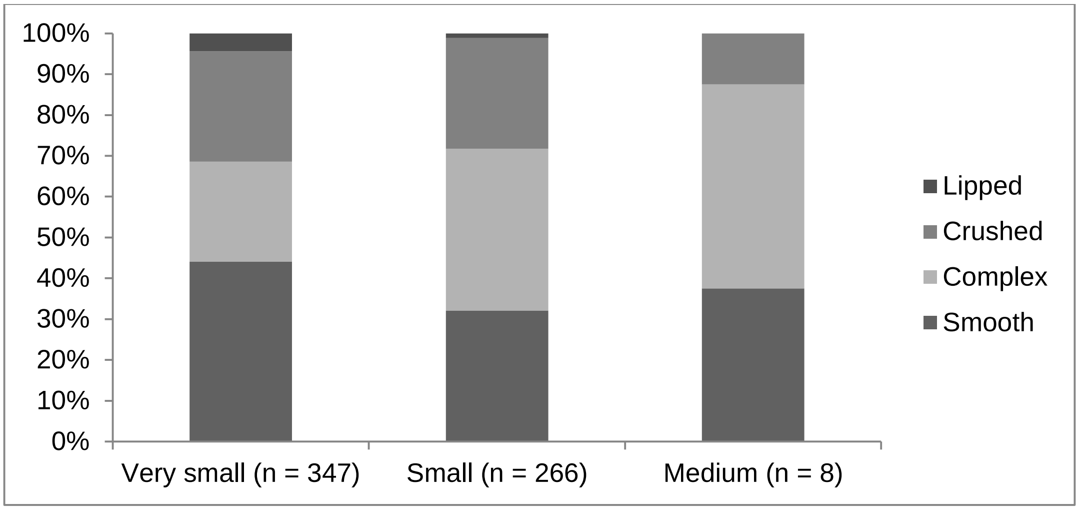

Figure 35. Platform types on proximal flakes in Susitna River 3 C3.

Figure 36. Lithic tools from Susitna River 3 C3 assemblage. Top row: hafted bifacial knife, hafted bifacial point bases, finished biface tip; middle row: retouched flake, retouched flake; bottom row: retouched flake, end scraper.

stage biface combination tool, both with secondary cortex. Flake tool blanks dominate the tool assemblage, with lesser amounts of biface thinning flake tool blanks and one each of biface, blade-like flake, cortical spall, and microblade tool blanks (Figure 37). There are no cores in the C3 assemblage.

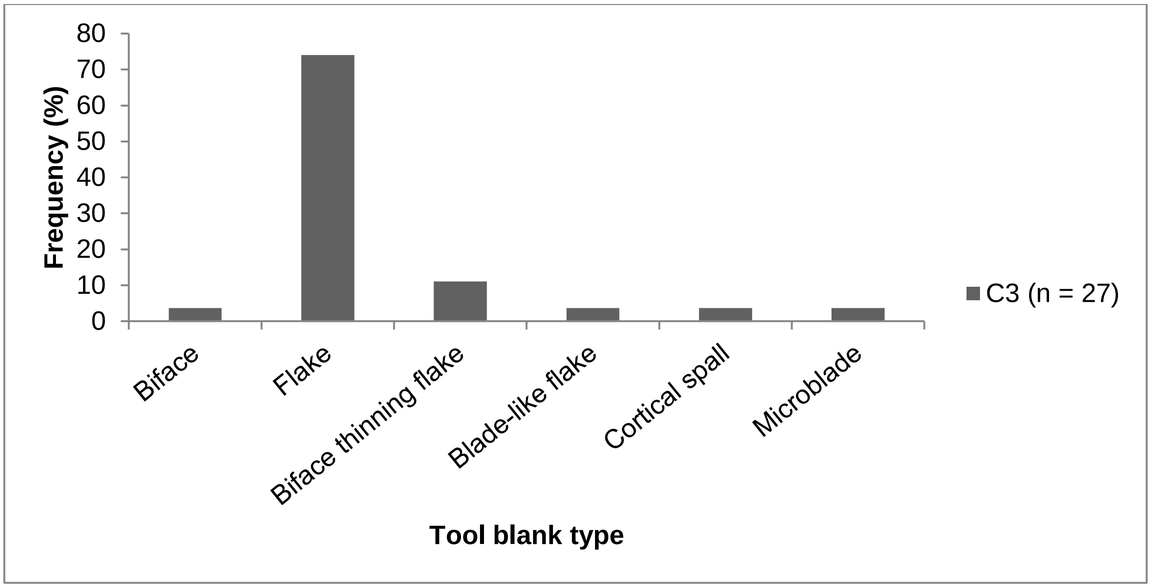

Figure 37. Tool blank type for Susitna River 3 C3.

Lithic raw material procurement. The majority of debitage and tools in the C3 assemblage (74.2%) are made on locally available lithic raw materials that were collected during lithic raw material survey (Table 20). Several raw material classes exhibit within-class diversity: there are 18 types of chalcedony, 10 types of chert, 8 types of rhyolite, and 2 types of andesite, while the remaining raw material classes are represented by a single type each. The most common raw material types in the assemblage are a medium light gray (N6) to medium gray

(N5) with black (N1) speckles chalcedony (36.3% of assemblage) and dark gray (N3) basalt (32.6% of assemblage) available in the Butte Creek drainage 13 km to the south of the site. Basalt and chalcedony debitage peices in the assemblage bear cortex, supporting local procurement; in fact six of the seven cortical chalcedony debitage pieces are on the medium light gray to medium gray material. The single metasedimentary cortical spall in the assemblage represents the naturally occurring bedrock at the site, a coarse-grained, poor-quality metamorphosed sedimentary rock that outcrops at numerous locations on the site. Approximately half (52.9%) of the cortical spalls bear secondary cortex, the remaining cortex appears to be primary.

The chalcedony and basalt lithic raw materials that dominate the assemblage were likely procured locally. A small amount of the chert in the assemblage matches material collected during our raw material survey, but the majority of this material appears to have been carried into the study area. The rhyolite and andesite appear to have been procured outside of the study area. Obsidian debitage occurs in the assemblage, but none if it was of suitable size for PXRF analysis; nevertheless, there are no known sources of obsidian nearby the study area, so this material minimally represents non-local procurement, but probably long-distance procurement.

Primary reduction. Primary reduction was a moderate component of lithic technological activities during the C3 occupation (36.7% of debitage assemblage). This is supported by the relatively low frequency of core reduction flakes and cortical spalls in the debitage assemblage, the low frequency of medium and large debitage, and the low frequency of smooth platforms on small and medium debitage. There are higher than expected counts of andesite, basalt, and rhyolite primary debitage; the differences in proportion of primary versus secondary debitage by raw material are significant ($\chi^2 = 14.803$, $df = 5$, $p < 0.0112$). This suggests that primary reduction focused on andesite, basalt, and rhyolite. Flake fragments in the assemblage likely represent informal core reduction, mostly focused on andesite, chalcedony, and basalt. Most raw materials in the assemblage appear to have been reduced elsewhere and carried to the study area. The exception is the chalcedony and basalt discussed above, which appear to have undergone initial reduction onsite.

There are no cores in the C3 assemblage that can be used to characterize formality of core preparation and reduction, but the single bladelet core-trimming flake suggests that formal, prepared cores were reduced onsite. Tools are primarily made on informal flake tool blanks, suggesting informal core reduction, but the presence of biface, biface-thinning flake, and microblade tool blanks suggests that some formal core reduction occurred. There is evidence for tool recycling in the assemblage; there is one end scraper on a flake that was initially flaked into an early stage biface, and the previously described early stage biface that was utilized as a tool, creating stepped retouch along the utilize edge.

Secondary reduction. Secondary reduction was a significant component of lithic technological activities in the Susitna River 1 C3 assemblage (63.4% of debitage assemblage). There are higher than expected counts of chalcedony and chert secondary debitage; the differences in proportion of primary versus secondary debitage by raw material are significant ($\chi^2 = 14.803$, $df = 5$, $p < 0.0112$). This suggests that primary reduction focused on chalcedony and chert. Secondary reduction activities during the C3 occupation consisted of biface production, and bifacial and unifacial tool maintenance. While typological biface thinning flakes only make up a small portion of the assemblage, the high number of complex platforms on small and medium debitage suggests biface production. A focus on tool maintenance is supported by the overwhelming frequency of retouch chips and retouch chip fragments (55.4% of debitage assemblage), and the high frequency of smooth and complex platform types on very small debitage, as well as the frequency of very small lipped platforms suggesting pressure flaking of bifacial tools. A focus on secondary reduction is supported by the overall minor component of core reduction flakes and cortical spalls in the debitage assemblage.

Tools in the C3 assemblage are predominantly lightweight, informal tool types. The majority of tools were discarded broken. Complete tools from the assemblage are relatively lightweight, with a mean weight of 1.4 g. Chert and rhyolite raw materials have the highest ratio of formal tools. Chert unifacial tools were retouched on the most available margins (76.5%), while chalcedony, basalt, and rhyolite unifacial tools were retouched on about 50% of their available margins (Table 17). Similarly, chert unifacial tool have a higher retouch index (0.71) than basalt (0.53), rhyolite (0.25), and chalcedony (0.22) unifacial tools (Table 18). The slightly higher tool to debitage ratios for chert and rhyolite may indicate that these materials were carried onsite in the form of tools, while tools made on basalt and chalcedony were made onsite. Chert tools were intensively retouched, while other raw material types exhibit low to moderate retouch.

These data indicate that secondary reduction dominated technological activities at the site, in the form of biface production and bifacial and unifacial tool maintenance. Tool production was mostly informal; informal tools were made on locally available lithic raw material and discarded with remaining utility. Formal tools are also represented in the assemblage; high quality, non-local lithic raw materials like chert and rhyolite were more likely to be made into formal tool types, and chert tools were more likely to be maintained.

Alpine Creek 8 (HEA-460)

There is one component represented at Alpine Creek 8. Component 1 (C1) consists of 1306 lithic artifacts recovered from the surface and shallowly buried contexts, in what has been provisionally interpreted to represent a LH occupation.

Alpine Creek Component 1 lithic assemblage. The C1 lithic assemblage consists of 1296 debitage, 9 tools, and 1 core. There are five raw material classes in the assemblage. The assemblage is dominated by argillite, with lesser amounts of chert, and minor amounts of chalcedony, rhyolite, and basalt (Table 24). The C1 debitage assemblage is dominated by flake fragments, with lesser amounts of retouch chip fragments, core reduction flakes, biface thinning flakes, and retouch chips, and minor amounts of cortical spalls, shatter, bladelet, and microblade fragments, and a single unworked gravel (Table 25). Debitage in the C1 assemblage is small, with lesser amounts of very small debitage, and few medium and large debitage pieces (Figure 38). Platform types for all debitage are primarily smooth, with lesser amounts of complex and crushed types (Figure 39). Platform types on very small flakes are dominated by smooth types, with few crushed and complex types. Platform types on small flakes are predominantly smooth, with lesser amounts of complex types, and few crushed types. Platform types on medium flakes are primarily complex, with slightly lesser amounts of smooth and crushed platform types. Platform types on large flakes in the assemblage are split evenly between complex and smooth (Figure 40).

There are nine tools in the assemblage, primarily retouched flakes and fragments, but including an early stage biface, hafted bifacial point fragment, and side scraper fragment (Figure 41). Most of the tools are made on argillite; none of the tools bears cortex. The most common tool blank type is flake (eight

Table 24. Alpine Creek 8 (HEA-460) C1 lithic raw material class by component.

Raw Material	Debitage *n (%)*	Tools/cores *n (%)*	Total *n (%)*	Local *%*
Chert	70 (5.4)	1 (10.0)	71 (5.4)	0
Basalt	2 (0.2)	-	2 (0.2)	100
Rhyolite	3 (0.2)	-	3 (0.2)	0
Chalcedony	14 (1.1)	-	14 (1.1)	100
Argillite	1207 (93.1)	9 (90.0)	1216 (93.1)	100
Total	1296	10	1306	94.3

Table 25. Alpine Creek 8 (HEA-460) artifact type by raw material class.

Artifact type	Chert n (%)	Basalt n (%)	Rhyolite n (5)	Chalcedony n (%)	Argillite n (%)	Total n (%)
Flake fragment	54 (77.1)	-	-	4 (28.6)	487 (40.3)	545 (42.1)
Flake	4 (5.7)	1 (50.0)	1 (33.3)	3 (21.4)	178 (14.7)	187 (14.4)
Cortical spall fragment	-	-	-	-	5 (0.4)	5 (0.4)
Primary cortical spall	-	-	-	-	3 (0.2)	3 (0.2)
Secondary cortical spall	-	-	-	-	3 (0.2)	3 (0.2)
Retouch chip fragment	8 (11.4)	-	-	4 (28.6)	320 (26.5)	332 (25.6)
Retouch chip	-	1 (50.0)	-	3 (21.4)	100 (8.3)	104 (8.0)
Biface thinning flake	3 (4.3)	-	2 (66.7)	-	103 (8.5)	108 (8.3)
Shatter	-	-	-	-	4 (0.3)	4 (0.3)
Unworked gravel	1 (1.4)	-	-	-	-	1 (0.1)
Bladelet fragment	-	-	-	-	2 (0.2)	2 (0.2)
Microblade fragment	-	-	-	-	2 (0.2)	2 (0.2)
Debitage subtotal	*70*	*2*	*3*	*14*	*1207*	*1296*
Hafted bifacial point fragment	-	-	-	-	1 (12.5)	1 (11.1)
Early stage biface	-	-	-	-	1 (12.5)	1 (11.1)
Retouched flake fragment	-	-	-	-	5 (62.5)	5 (55.6)
Retouched flake	-	-	-	-	1 (12.5)	1 (11.1)
Side scraper fragment	1 (100)	-	-	-	-	1 (11.1)
Tool subtotal	*1*	-	-	-	*8*	*9*
Simple flake core	-	-	-	-	1 (100)	1 (100)
Core subtotal	-	-	-	-	*1*	*1*
Formal:informal	1:0 0	-	-	-	2:6 0.3	3:6 0.5
Complete: broken	0:1 0	-	-	-	2:6 0.3	2:7 0.3
Mean complete tool weight	-	-	-	-	73.2	73.2
Tool:debitage	0.01	-	-	-	0.01	0.01

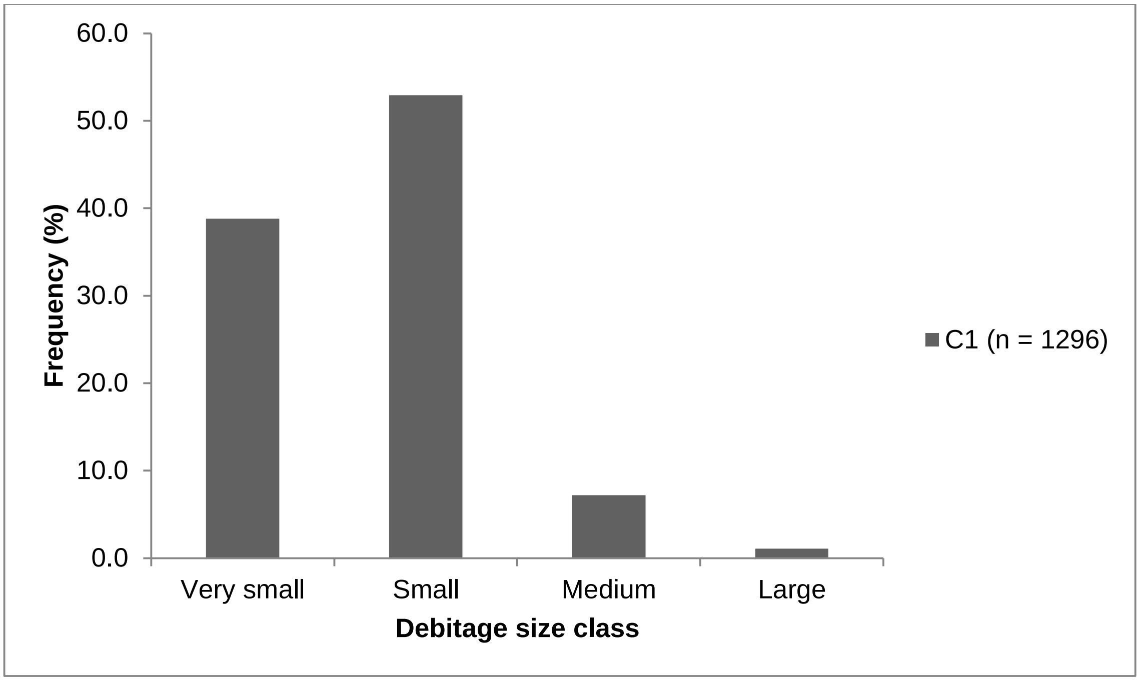

Figure 38. Debitage size for Alpine Creek 8 C1.

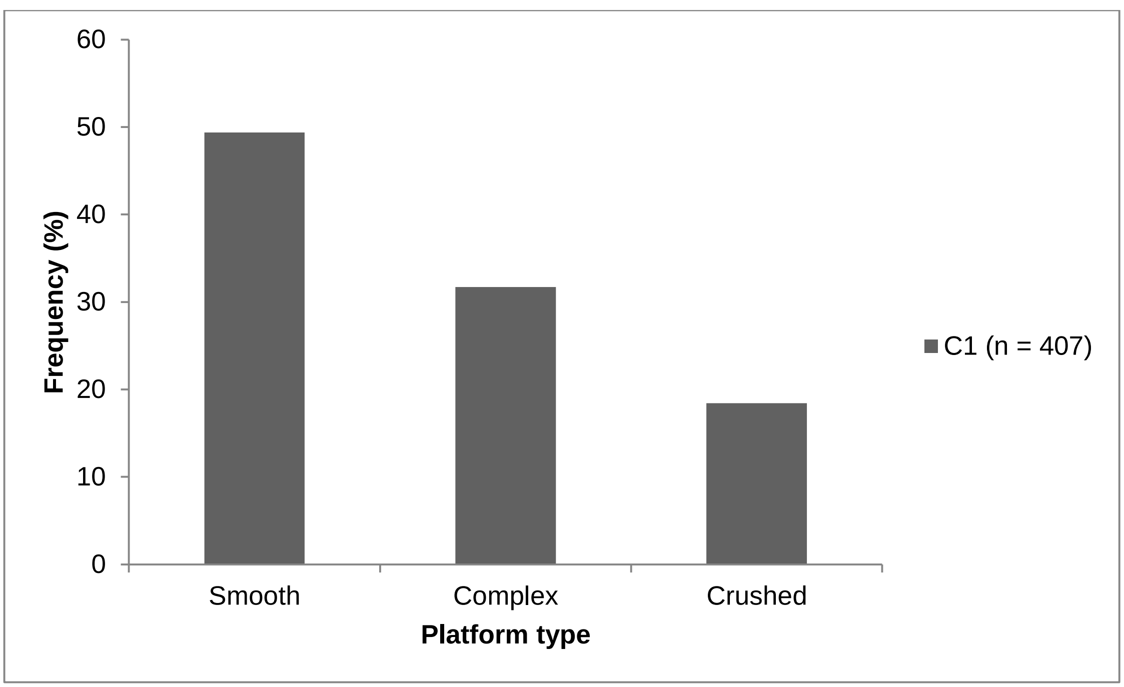

Figure 39. Platform type for all proximal debitage in Alpine Creek 8 C1.

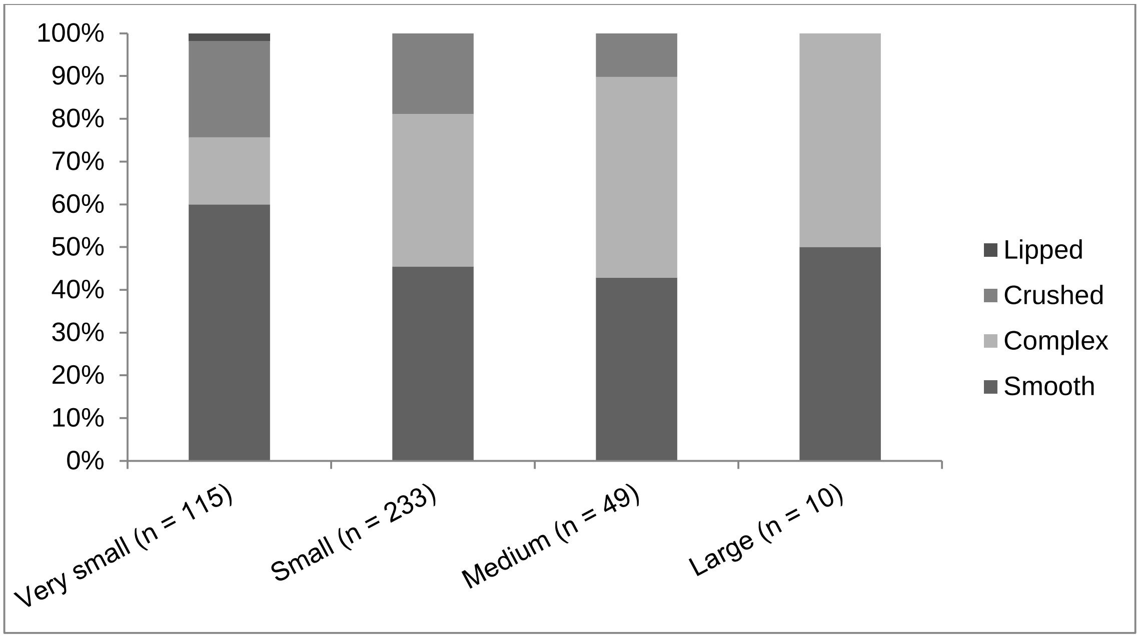

Figure 40. Platform type by flake size class in Alpine Creek 1 C1.

Figure 41. Lithic tools from Alpine Creek 8 C1 assemblage. From left: hafted biface, early stage biface, flake core (top), retouched flake (bottom), retouched flake (top), retouched flake (bottom).

of the nine tool blanks, 89% of blanks), but the hafted biface was made on a biface tool blank (Figure 42). Tools were frequently discarded broken, and are generally heavy (Table 25). There is a single core in the C1 assemblage, an argillite simple flake core weighing 19.6 g, with a maximum linear dimension of 38.73, combining for a size value of 759. The core has two discernible platforms, both of which are smooth, and has four core fronts.

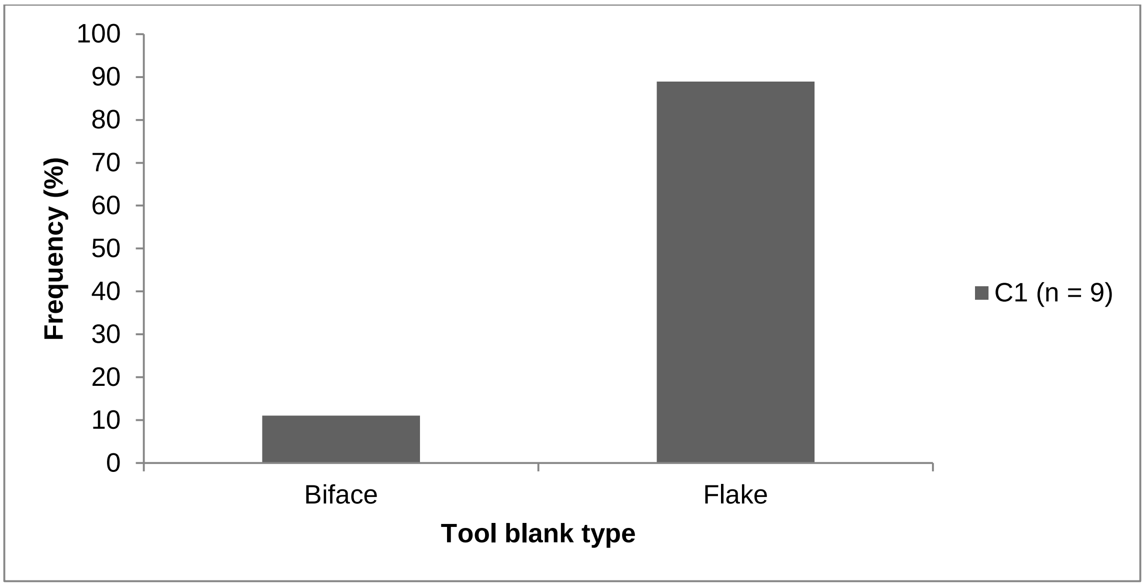

Figure 42. Tool blank type for all tools in Alpine Creek 8 C1.

Lithic raw material procurement. Most of the lithic raw materials in the C1 assemblage were procured locally (94.3%). This high number primarily represents a greenish gray (5GY 6/1) argillite that is locally available throughout the Alpine Creek valley, including the drift gravels in the landform upon which the site is situated; this single raw material type comprises 93.0% of the lithic raw material in the assemblage. Accordingly, there is little diversity within the raw material classes at the site: there are two types of chert, and one type each of chalcedony, basalt, rhyolite, metavolcanic, and metasedimentary raw material types in the assemblage. The only tool not made on the locally available argillite is a chert side scraper fragment. Only the greenish-gray argillite in the assemblage bears cortex, with the appearance of both secondary (41.6%) and primary (58.4%) cortex.

The argillite that dominates the C1 assemblage was procured locally in the Alpine Creek valley, from drift gravels in the valley (and possibly at the site), as well as from primary geologic context, probably from outcrops in the valley walls. Chalcedony and basalt in the assemblage are also locally available, while the chert in the assemblage does not match any chert types collected during our raw material survey, and was probably carried into the site from a non-local source. The chert side scraper may have been carried onsite as a finished tool. These data suggest that lithic raw material procurement was focused on locally available lithic raw materials, primarily available within 1 km of the site.

Primary reduction. Primary reduction of locally available argillite was a significant part of lithic technological activities at Alpine Creek 8 (58.0%). This is supported by the relatively high frequency of core reduction flakes and flake fragments, the presence of an argillite flake core, and the larger size of flakes in the assemblage. There are higher than expected counts of chert primary debitage, suggesting primary reduction focused on chert; differences in the proportions of primary versus secondary debitage for each raw material are significantly different ($\chi^2 = 21.617$, $df = 2$, $p < .0001$).

Primary reduction of argillite appears to have focused on informal flake core reduction, as evidenced by the flake core and smooth platforms on small, medium, and large debitage. A high frequency of flake fragments indicates the informal nature of core reduction, but may also speak to the brittle nature of the locally available argillite reduced at the site. Bifacial core reduction may have been a significant part of primary reduction, as demonstrated by the frequency of complex platforms on small, medium, and large debitage, and the early stage biface in the assemblage. The frequency of argillite cortical debitage suggests that some initial reduction occurred at the site, but that most initial reduction probably occurred elsewhere. This is somewhat surprising given the close proximity of knappable nodules of argillite to the site. Informal core reduction is supported by the high frequency of tools made on flake blanks, but the single biface tool blank also demonstrates bifacial core reduction. There is no evidence for bipolar reduction or tool recycling.

Secondary reduction. Secondary reduction was a slightly less significant lithic technological activity at Alpine Creek 8 (42.0% of debitage assemblage). There are higher than expected counts of argillite secondary debitage, suggesting secondary reduction focused on argillite; differences in the proportions of primary versus secondary debitage for each raw material are significantly different ($\chi^2 = 21.617$, $df = 2$, $p < .0001$). Secondary reduction activities in the C1 assemblage focused on maintenance of unifacial tools, but also consisted of some bifacial tool maintenance, supported by the number of retouch chips and fragments, as well as the high frequency of very small debitage with smooth platforms. In addition, biface production was a significant part of secondary reduction activities at the site, as supported by the frequency of small debitage with complex platforms and the small number of biface thinning flakes.

Tools in the C1 assemblage are primarily informal, but formal types include bifaces and a scraper. Tools in the assemblage are very heavy, although the mean weight has a large standard deviation due to a heavy argillite early stage biface (119.3 g) and a heavy argillite retouched flake (138.6 g) representing a large flake blank with a cortical platform that was used as a tool, resulting in stepped and use-wear retouch. Argillite unifacial tools in the assemblage have been retouched on 53.8% of available edges, while the single chert scraper fragment was retouched on 100% of available edges. Similarly, the chert scraper has a retouch index score of 0.57, while argillite tools have a mean retouch index score of 0.14, indicating that the chert tool was more intensively reworked than the locally available argillite. Low tool-to-debitage ratios for argillite and chert suggest that tools made on these materials were produced onsite. These data indicate that secondary reduction at Alpine Creek 8 focused on biface production and unifacial tool maintenance, and that tools were mostly informal types. Tools were retouched with low to moderate intensity, with the most intense maintenance focused on non-local chert tools.

Butte Creek 1 (HEA-499)

There are two components represented at Butte Creek 1. Component 2 (C2) consists of approximately 3100 fragments of animal bone (Mueller 2015) and 50 lithics in a LH context (post-dating deposition of the Devil tephra at 1500-1300 cal BP); component 1 (C1) consists of approximately 10,600 fragments of animal bone (Mueller 2015) and 769 lithics in a MH context (4867-4432 cal BP). The C2 assemblage is small and is not discussed in detail here.

Butte Creek 1 component 1 lithic assemblage. The lithic assemblage from C1 consists of 751 debitage and 18 tools. There are eight classes of lithic raw materials. The C1 lithic assemblage is dominated by basalt and chalcedony, with lesser amounts of argillite, chert, andesite, and rhyolite, and minor amounts of obsidian and metavolcanic rock (Table 26). The debitage assemblage from C1 is dominated by retouch chip fragments and retouch chips, with lesser amounts of flake fragments, core reduction flakes, and biface thinning flakes, and minor amounts of cortical spalls and one initially flaked gravel (Table 27).

Table 26. Butte Creek 1 (HEA-499) lithic raw material classes by component.

	Component 1				Component 2			
	Debitage	Tools/Cores	Total	Local	Debitage	Tools	Total	Local
Raw Material	*n (%)*	*n (%)*	*n (%)*	*%*	*n (%)*	*n (%)*	*n (%)*	*%*
Chert	61 (8.1)	4 (22.2)	65 (8.5)	6.2	1 (2.0)	1 (100)	2 (4.0)	0
Obsidian	6 (0.8)	1 (5.6)	7 (0.9)	0	1 (2.0)	-	1 (2.0)	0
Basalt	330 (43.9)	3 (16.7)	333 (43.3)	100	4 (8.2)	-	4 (8.0)	100
Rhyolite	17 (2.3)	3 (16.7)	20 (2.6)	0	-	-	-	-
Chalcedony	211 (28.1)	6 (33.3)	217 (28.2)	59.4	41 (83.7)	-	41 (82.0)	14.6
Argillite	88 (11.7)	-	88 (11.4)	100	1 (2.0)	-	1 (2.0)	100
Andesite	37 (4.9)	-	37 (4.8)	0	1 (2.0)	-	1 (2.0)	100
Metavolcanic	1 (0.1)	1 (5.6)	2 (0.3)	0	-	-	-	-
Total	751	18	769	72.0	49	1	50	24.0

Table 27. Butte Creek 1 (HEA-499) C1 artifact type by raw material class.

Artifact type	Chert n (%)	Obsidian n (%)	Basalt n (%)	Rhyolite n (%)	Chalcedony n (%)	Argillite n (%)	Andesite n (%)	Metavolcanic n (%)	Total n (%)
Flake fragment	8 (13.1)	4 (66.7)	59 (17.9)	4 (23.5)	57 (27.0)	15 (17.0)	3 (8.1)	1 (100)	151 (20.1)
Flake	7 (11.5)	1 (16.7)	33 (10.0)	7 (41.2)	25 (11.8)	10 (11.4)	9 (24.3)	-	92 (12.3)
Cortical spall fragment	-	-	2 (0.6)	-	1 (0.5)	2 (2.3)	-	-	5 (0.7)
Primary cortical spall	-	-	1 (0.3)	-	-	-	-	-	1 (0.1)
Secondary cortical spall	-	-	2 (0.6)	-	1 (0.5)	-	-	-	3 (0.4)
Retouch chip fragment	16 (26.2)	-	135 (40.9)	4 (23.5)	75 (35.5)	36 (40.9)	15 (40.5)	-	281 (37.4)
Retouch chip	25 (41.0)	1 (16.7)	86 (26.1)	1 (5.9)	42 (19.9)	15 (17.0)	4 (10.8)	-	174 (23.2)
Biface thinning flake	4 (6.6)	-	12 (3.6)	1 (5.9)	10 (4.7)	10 (11.4)	6 (16.2)	-	43 (5.7)
Initially flaked gravel	1 (1.6)	-	-	-	-	-	-	-	1 (0.1)
Debitage subtotal	*61*	*6*	*330*	*17*	*211*	*88*	*37*	*1*	*751*

Table 27. (Continued)

Artifact type	Chert n (%)	Obsidian n (%)	Basalt n (%)	Rhyolite n (%)	Chalcedony n (%)	Argillite n (%)	Andesite n (%)	Metavolcanic n (%)	Total n (%)
Hafted bifacial knife	1 (25.0)	-	-	-	-	-	-	-	1 (5.9)
Middle stage biface fragment	1 (25.0)	-	-	-	1 (16.7)	-	-	-	2 (11.8)
Retouched flake fragment	-	-	2 (66.7)	1 (33.3)	2 (33.3)	-	-	-	5 (29.4)
Retouched flake	-	1 (100)	1 (33.3)	-	1 (16.7)	-	-	-	3 (17.6)
End scraper on flake fragment	1 (25.0)	-	-	1 (33.3)	-	-	-	-	2 (11.8)
Circular end scraper fragment	-	-	-	1 (33.3)	-	-	-	-	1 (5.9)
Single-straight side scraper	1 (25.0)	-	-	-	-	-	-	-	1 (5.9)
Single-convex side scraper fragment	-	-	-	-	1 (16.7)	-	-	-	1 (5.9)
Utilized pebble	-	-	-	-	1 (16.7)	-	-	-	1 (5.9)
Tool subtotal	*4*	*1*	*3*	*3*	*6*	-	-	-	*17*
Simple flake core fragment	-	-	-	-	-	-	-	1 (100)	1 (100)
Core subtotal	-	-	-	-	-	-	-	*1*	*1*
Formal:informal	4:0 -	0:1 0	0:3 0	2:1 2	2:4 0.5	-	-	-	8:9 0.9
Complete: broken	2:2 1	1:0 -	2:1 2	0:3 0	2:4 0.5	-	-	-	7:10 0.7
Mean complete tool weight	24.3	0.3	0.9	-	3.6	-	-	-	8.3
Tool:debitage	0.07	0.17	0.01	0.18	0.03	-	-	-	0.02

Debitage in the C1 assemblage is primarily very small, with lesser amounts of small and medium debitage, and a single piece of large debitage (Figure 43). Platform types for all proximal flakes in the C1 assemblage are primarily smooth, with lesser amounts of crushed and complex platforms (Figure 44). Platform types in very small proximal debitage are primarily smooth, with lesser amounts of crushed and very few complex platforms. Platform types in small proximal debitage are primarily smooth and crushed, with lesser amounts of complex platforms. Platform types on the two medium proximal debitage are complex (Figure 45).

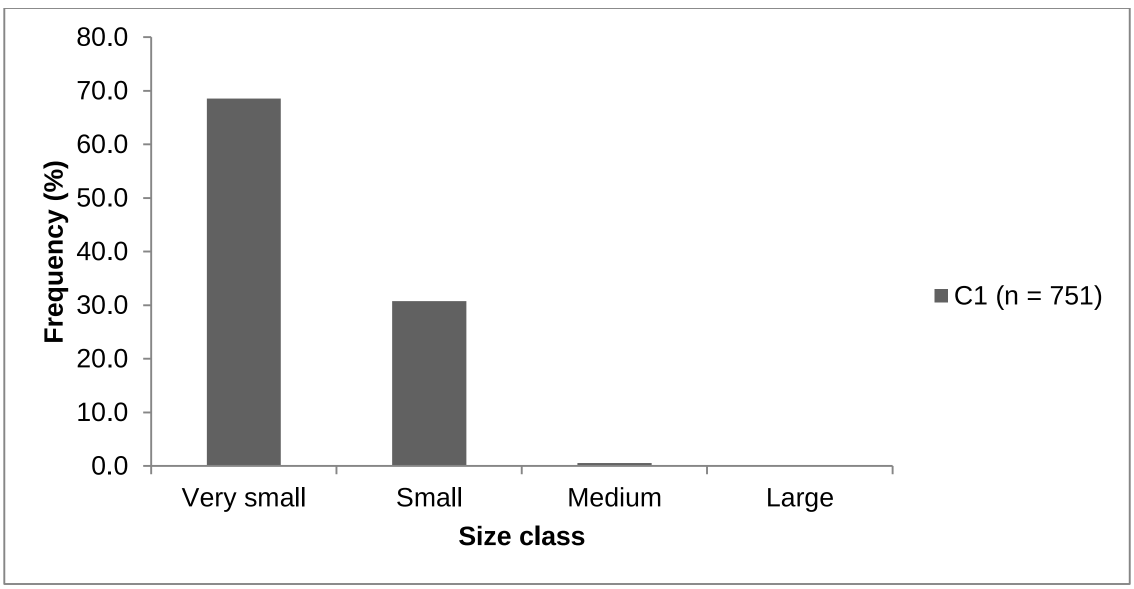

Figure 43. Butte Creek 1 C1 debitage size class.

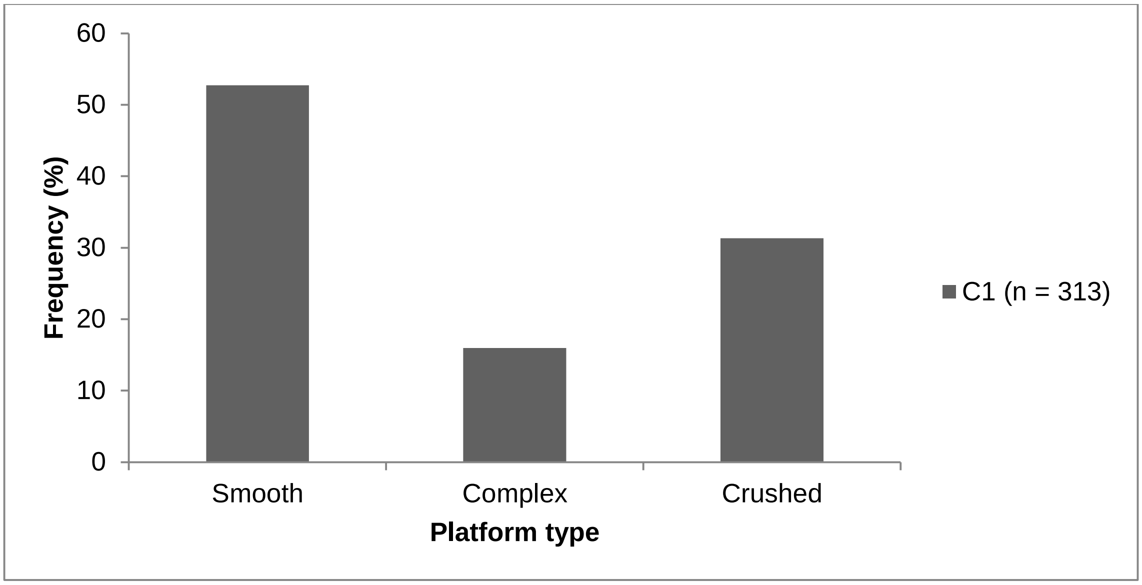

Figure 44. Platform types for proximal debitage in Butte Creek 1 C1.

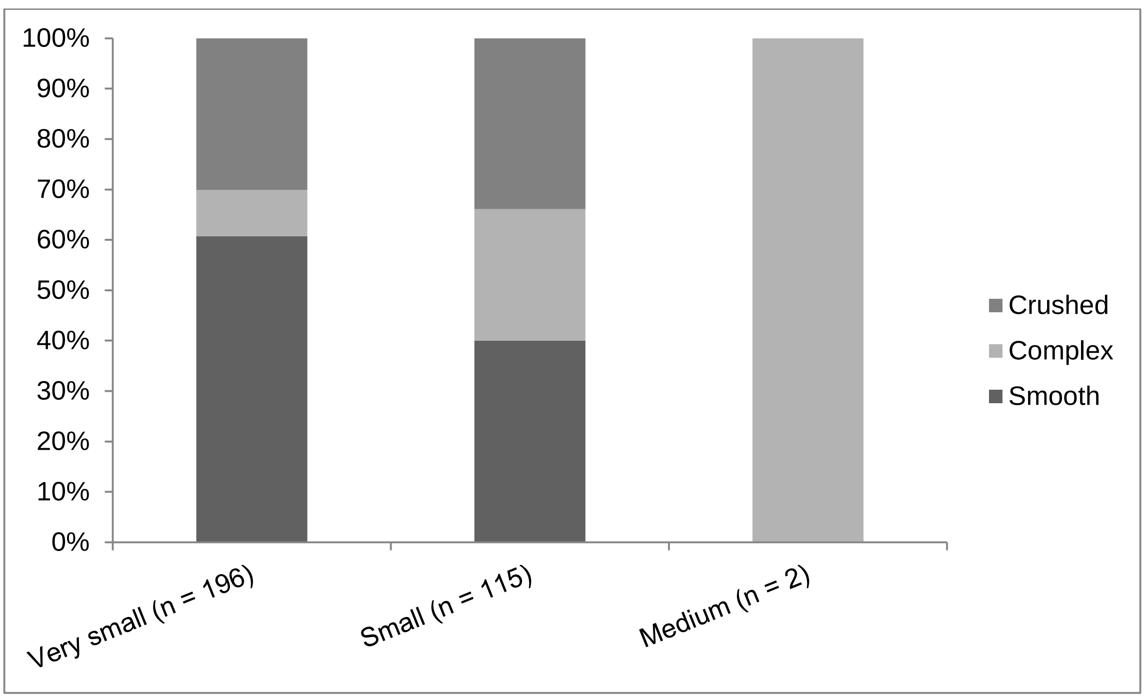

Figure 45. Platform types for each size class in Butte Creek 1 C1.

There are 17 tools in the C1 assemblage, primarily retouched flakes, but also bifaces, scrapers, a knife, and utilized pebble (Table 27, Figure 46). Tools are made primarily on flake blanks, but biface, cortical spall, and pebble blanks are represented as well (Figure 47). Tools in the assemblage were primarily discarded after breaking, but there are many tools that were discarded complete. The tool assemblage is almost evenly comprised of formal and informal tool types. Mean tool weight is 8.3 g, but this has a standard deviation of 15.3 because a single side scraper weighs 40.1 g (Table 27).

Tools are primarily produced on chalcedony, but also on chert, basalt, rhyolite, and obsidian (Table 26). Four of the tools have cortex, a chalcedony side scraper, a chalcedony retouched flake, a chalcedony utilized pebble, and a rhyolite circular end scraper. All tool cortex is secondary indicating procurement from gravel sources. Chert tools have the highest percentage of retouched edge units, followed by rhyolite, basalt, chalcedony, and obsidian (Table 17). Similarly, chert tools have the highest retouch index, followed by rhyolite and chalcedony; basalt and obsidian tools have a low retouch index (Table 18). There is one core in the C1 assemblage, a simple flake core fragment made on metavolcanic rock, with three core fronts, weighing 6.3 g, with a MDL of 28.42 and size class of 179. There are no platforms on the fragment, but it appears to have had two platforms. The core has no cortex remaining on it. There is no evidence of tool recycling or scavenging.

Figure 46. Lithic tools from the Butte Creek 1 C2 assemblage. Top row: endscraper, sidescraper, endscraper, sidescraper; bottom row (left to right) bifacial knife, middle stage biface, middle stage biface, retouched flake, retouched flake.

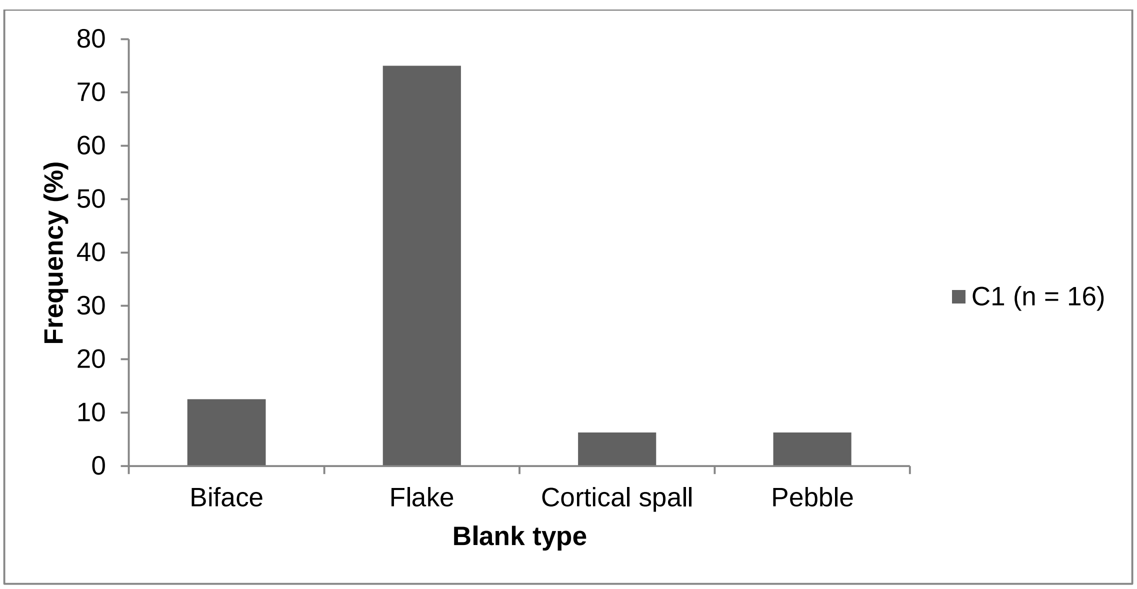

Figure 47. Tool blank type for tools in Butte Creek 1 C1.

Lithic raw material procurement. The majority of lithics in the Butte Creek 1 C1 assemblage (72.0%) were made on lithic raw materials that we identified during our raw material survey of the study area (Table 26). There is considerable variety in the raw material classes represented at the site; there are 15 types of chalcedony, seven types of chert, four types of rhyolite, two types each of basalt and andesite, and one type each of obsidian and metavolcanic rock. The most numerous raw material types are a dark gray (N3) basalt (43% of assemblage), a medium light gray (N6) to medium gray (N5) chalcedony with black (N1) speckles (14.0 % of assemblage), and a greenish gray (5GY 6/1) argillite (11.4% of assemblage). The basalt and chalcedony were collected in the Butte Creek drainage less than 1 km southwest of the site; the argillite was collected in drainages on the southern flank of the Clearwater Mountains and in the Alpine Creek valley. Cortical debitage on basalt, chalcedony, and argillite raw materials and cortical surfaces on chalcedony tools supports local procurement of these lithic raw materials.

A small amount of the chert in the assemblage matches material collected during our raw material survey, but the majority of this material appears to have been carried into the study area. The rhyolite and andesite in the assemblage were not collected during our raw material survey of the study area, and are presumed to represent non-local procurement. The rhyolite tool in the assemblage that bears cortex could indicate that rhyolite was available just outside of the study area, but the lack of rhyolite cortical debitage in the assemblage suggests that this represents a rhyolite tool made elsewhere and carried onto the site.

There are seven obsidian artifacts in the C1 assemblage, but only three of these were of suitable size for geochemical characterization. PXRF analysis of the obsidian retouched flake indicates it was made on obsidian from the A prime source (AOD-12608), while two obsidian debitage pieces were made on obsidian from the A prime source the Batza Téna source (Table 19). The location of the A prime source is currently unknown, but the Batza Téna source is 435 km NW of the site, indicating some long-distant transport of lithic raw materials. These data indicate that overall lithic raw material procurement during the C1 occupation of Butte Creek 1 focused primarily on locally available raw materials, often within 1 km. There is evidence of some non-local procurement, primarily of chert and rhyolite, as well as long-distance transport of obsidian.

Primary reduction. There is limited evidence for primary reduction during the C1 occupation of Butte Creek 1 (33.7% of debitage assemblage). Core reduction flakes comprise 12.3% of the C1 assemblage, and cortical spalls are also present. While the debitage assemblage is comprised mostly of very small debitage, there is a relatively high frequency of small debitage, and the majority of proximal small debitage has smooth platforms. There are two medium size flakes with complex platforms; both of these are made on basalt. This suggests basalt biface core reduction occurred at the site, but was a minor component of primary reduction. There are higher than expected counts of chalcedony and rhyolite primary debitage, suggesting primary reduction focused on these materials. The proportion of primary versus secondary debitage for each raw material is significantly different ($X^2 = 23.968$, df = 6, $p < 0.0005$).

The frequency of chalcedony, rhyolite, basalt, and argillite flake fragments suggests these materials were reduced using informal core techniques. Reduction of basalt and chalcedony flake cores appears to be the most common primary reduction activity at the site. Interestingly, there is just one piece of metavolcanic debitage that matches the metavolcanic flake core, suggesting this core was not intensively reduced on site. The lack of cortical debitage on chert, andesite, and obsidian artifacts indicates that these materials were initially reduced elsewhere. The flake core fragment and high frequency of flake blanks suggests that overall core reduction was informal. There is no evidence for bipolar knapping or scavenging in the assemblage. These data indicate that primary reduction was a minor component of lithic reduction activities occurring during the C1 occupation of Butte Creek 1, and was focused on informal reduction of locally available raw materials, as well as non-local rhyolite.

Secondary reduction. Secondary reduction was a significant component of lithic technological activities occurring during the C1 occupation of Butte Creek 1 (66.3% of debitage assemblage). This is supported by the high frequency of retouch chips and fragments and the high frequency of very small debitage. Most secondary reduction appears to have focused on unifacial tool maintenance, supported by the high number of smooth platforms on very small debitage. Biface production and maintenance was a minor component of secondary reduction activities, as evidenced by the low frequency of very small and small debitage with complex platforms. There are higher than expected counts of andesite, argillite, basalt, and chert secondary debitage, suggesting that secondary reduction focused on these raw materials. Differences in the proportions of primary versus secondary debitage for each raw material type are significant ($X^2 = 23.968$, df = 6, $p < 0.0005$).

Tools in the C1 assemblage are both formal and informal, generally heavier, and were discarded both broken and complete. This suggests raw material economization was not an important factor. Formal tools were made on non-local chert and rhyolite, and not surprisingly these tools were reduced more intensively than tools made on local materials, but the high frequency of retouch chips on local raw material suggests these materials may have been reduced intensively as well. Obsidian and rhyolite have the highest tool-to-debitage ratios, suggesting that obsidian and rhyolite tools may have been carried onsite in finished form and not intensively reduced.

Given the overall informal character of primary reduction occurring at Butte Creek 1, it appears that formal tools may have been carried onto the site. The single obsidian retouched flake was not reduced intensively. Although the source for A prime obsidian is not know, it likely represents long distance transport, so it is surprising that it was discarded early in its use life, again suggesting economization was not important. These data suggest that secondary reduction activities during the C1 occupation of the site focused on unifacial tool maintenance. Chert and rhyolite formal tools were more intensively maintained.

Windy Creek 1 (HEA-505)

There is one component represented at Windy Creek 1. Component 1 consists of 241 lithics collected from a surface context in the Clearwater Mountains. There are no dates associated with lithic assemblage; however, the site has many similarities to Alpine Creek 8 and may represent a LH occupation of the Clearwater Mountains. The assemblage is not useful as a temporal marker of lithic technology in the study area, but it is included her because it is a useful marker of general lithic technological activities in an alpine tundra setting of the Clearwater Mountains.

Windy Creek component 1 lithic assemblage. The lithic assemblage from C1 consists of 236 debitage and five tools. The assemblage has five classes of lithic raw materials. The lithic assemblage is dominated by argillite, with very little chalcedony, basalt, andesite, and obsidian (Table 28). The C1 debitage assemblage consists primarily of flake fragments, with lesser amounts of biface thinning flakes, retouch chip fragments, core-reduction flakes, cortical spalls, and retouch chips, minor amounts of shatter, and one initially flaked gravel (Table 29).

Table 28. Windy Creek 1 (HEA-505) lithic raw material types by component.

	Component 1			
Raw Material	Debitage *n (%)*	Tools *n (%)*	Total *n (%)*	Local *%*
Obsidian	1 (0.4)	-	1 (0.4)	0
Basalt	5 (2.1)	-	5 (2.1)	100
Chalcedony	14 (5.9)	1 (20)	15 (6.2)	86.7
Argillite	215 (91.1)	4 (80)	219 (90.9)	100
Andesite	1 (0.4)	-	1 (0.4)	0
Total (%)	236	5	241	98.3

Table 29. Windy Creek 1 (HEA-505) artifact type by raw material.

Artifact type	Obsidian n (%)	Basalt n (%)	Chalcedony n (%)	Argillite n (%)	Andesite n (%)	Total n (%)
Flake fragment	-	-	5 (35.7)	105 (48.8)	1 (100)	111 (47.0)
Flake	-	-	2 (14.3)	21 (9.8)	-	23 (9.7)
Cortical spall fragment	-	1 (20.0)	1 (7.1)	6 (2.8)	-	8 (3.4)
Retouch chip fragment	-	-	-	28 (13.0)	-	28 (11.9)
Retouch chip	-	-	-	12 (5.6)	-	12 (5.1)
Biface thinning flake	1 (100)	4 (80.0)	3 (21.4)	43 (20.0)	-	51 (21.6)
Shatter	-	-	2 (14.3)	-	-	2 (0.8)
Initially flaked gravel	-	-	1 (7.1)	-	-	1 (0.4)
Debitage subtotal	*1*	*5*	*14*	*215*	*1*	*236*
Middle stage biface fragment	-	-	-	1 (25.0)	-	1 (20.0)
Retouched flake fragment	-	-	1 (100)	2 (50.0)	-	3 (60.0)
End scraper on flake fragment	-	-	-	1 (25.0)	-	1 (20.0)
Tool subtotal	-	-	*1*	*4*	-	*5*
Formal:informal	-	-	0:1 0	2:2 1	-	2:3 0.7
Complete: broken	-	-	0:1 0	0:4 0	-	0:5 0
Mean complete tool weight	-	-	-	-	-	-
Tool:debitage	-	-	0.07	0.02	-	0.02

Debitage in the C1 assemblage is primarily small, with lesser amounts of very small and medium debitage, and few large debitage (Figure 48). Platform types for all proximal flakes are predominantly complex, with lesser amounts of smooth and crushed platform types (Figure 49). Platform types for very small, small, and large flakes are predominantly complex, with lesser amounts of smooth and crushed platform types. Platform types for medium flakes are predominantly complex, with lesser amounts of smooth platform type (Figure 50).

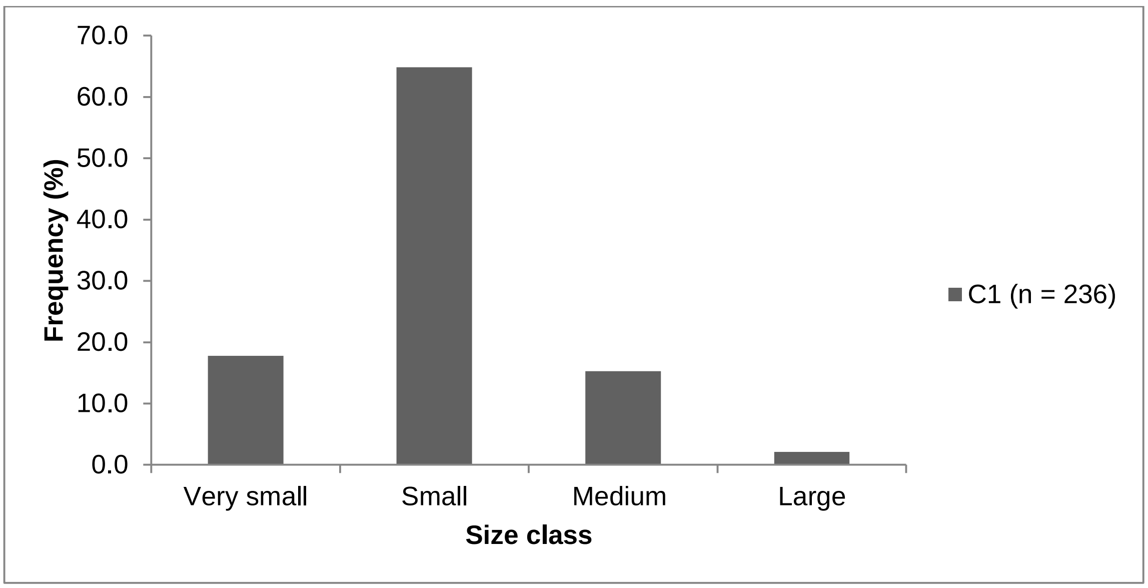

Figure 48. Debitage size class for Windy Creek 1.

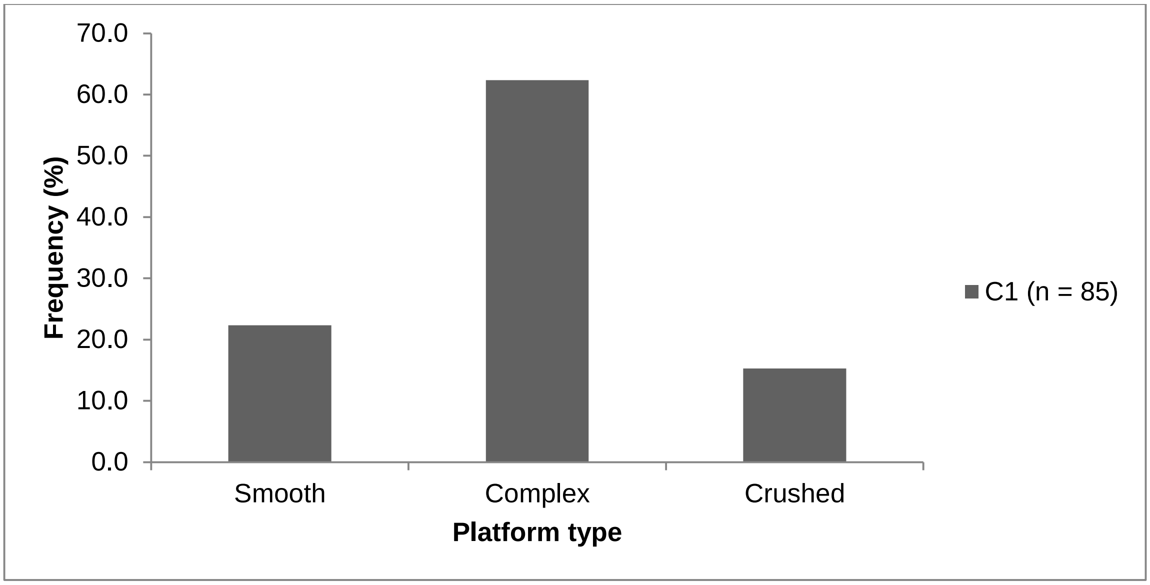

Figure 49. Proximal flake platform type for Windy Creek 1.

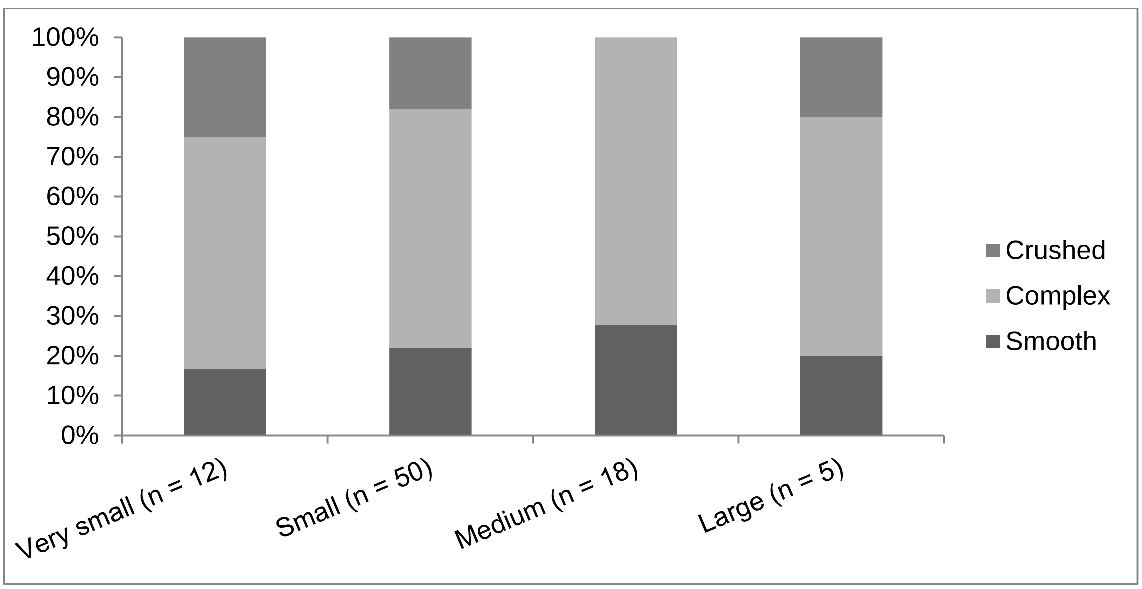

Figure 50. Platform type by size class for Windy Creek 1 C1.

There are five tools in the C1 assemblage, including retouched flakes, a biface, and a scraper (Table 29, Figure 51). The most common tool blank types are flake and biface thinning flake, represented by two tools each, along with a single cortical spall tool blank (Figure 52). There are an almost even amount of formal and informal tools in the tool assemblage. Most tools in the assemblage are broken, and the single complete tool is relatively heavy (Table 29). Four of the five tools are made on argillite, and one on chalcedony. One tool has cortex, an argillite retouched flake with primary cortex type. The chalcedony tool in the assemblage was retouched on 70.0% of available margins, and the argillite tools in the assemblage were retouched on 59.3% of margins (Table 17). The chalcedony tool has a retouch index of 0.1, and the argillite tools have a mean retouch index of 0.37 (Table 18). There are no cores in the C1 assemblage.

Figure 51. Lithic tools from the Windy Creek C1 assemblage. Clockwise from upper left: retouched flake, middle stage biface, retouched flake, retouched flake, endscraper.

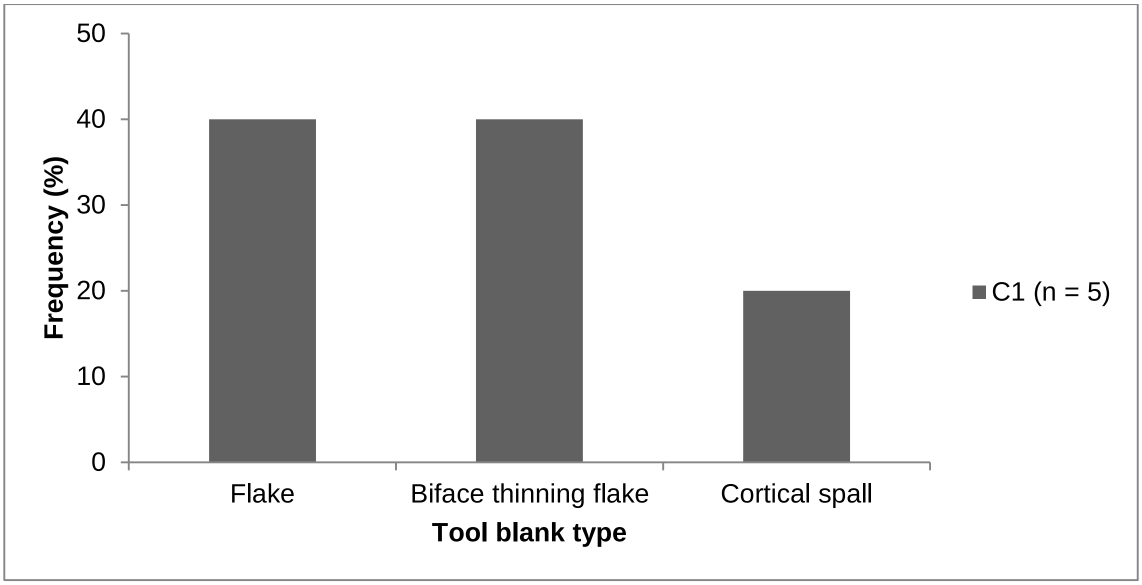

Figure 52. Tool blank type for Windy Creek 1 C1.

Lithic raw material procurement. The majority of lithics in the C1 assemblage (98.3%) are made on lithic raw materials that we collected during our raw material survey of the study area (Table 28). There is little diversity within the C1 raw material types; there are three types of chalcedony, and one type each of the remaining raw material classes. The assemblage is dominated by one type of argillite, a greenish gray (5GY 6/1) material (90.9% of the assemblage) that we collected south of the site in the Alpine Creek valley, approximately 5 km away. In addition, most of the chalcedony in the assemblage matches two types collected in our raw material survey of the Butte Creek drainage.

The andesite and obsidian in the assemblage were not located in our raw material survey and are considered to represent non-local procurement. The obsidian was too small to characterize geochemically, but likely represents long-distance procurement. These data suggest that lithic raw material procurement at the site focused primarily on locally available raw material, procured within 5 km of the site.

Primary reduction. Primary reduction was a significant part of lithic reduction activities at Windy Creek 1 (61.4% of debitage). This is supported by the high frequency of flake fragments likely representing informal core reduction, the frequency of cortical spalls, and the larger debitage size classes represented in the assemblage. The presence of large and medium size flakes with complex platforms suggests that bifacial core reduction occurred. There is no statistically significant difference in the proportions of argillite primary or secondary debitage when compared to the other raw material types ($\chi^2 = 0.002$, $df = 1$, $p = 0.9635$). Tool blank type supports biface core reduction and informal flake core reduction to produce tool blanks. There is no evidence for bipolar knapping or scavenging in the assemblage. These data suggest that primary reduction was a major component of lithic technological activities, and focused on both formal bifacial core and informal flake core reduction of locally available argillite.

Secondary reduction. Secondary reduction comprises 38.6% of debitage in the Windy Creek 1 assemblage. Secondary reduction consisted mostly of producing and maintaining bifacial tools, and some unifacial tool maintenance. Production of bifacial tools is supported by the high frequency of biface thinning flakes, and the high frequency of complex platforms, particularly on small and very small debitage. Unifacial tool maintenance is supported by smooth platforms on very small debitage. Tools were heavy, discarded when broken, and were generally not maintained intensively. These data indicate that secondary reduction at Windy Creek 1 consisted primarily of producing and maintaining bifacial tools, and that raw material economization was not an important factor.

Susitna Dune 4 (HEA-508)

There are two components represented at Susitna Dune 4. Component 3 (C3) consists of 132 lithics and two fragments of animal bone from a LH context (post-dating deposition of the Devil tephra 1500-1300 cal BP); component 2 (C2) consists of three lithics from a MH context, in the same stratigraphic position as Susitna Dune 1 C2 (7788-7627 cal BP). The MH component is small (Table 30), and is not discussed in detail here.

Susitna Dune 4 component 3 lithic assemblage. The lithic assemblage from C3 consists of 123 debitage and nine tools. The assemblage has seven classes of lithic raw materials. The lithic assemblage is dominated by chert, with lesser amounts of chalcedony and basalt, and minor amounts of rhyolite, obsidian, quartzite, and granite (Table 30). The C3 assemblage consists primarily of retouch chips and fragments, with lesser amounts of biface thinning flakes, flake fragments, and flakes, and just two cortical debitage (Table 31). Debitage in the C3 assemblage is primarily very small, with lesser amounts of

Table 30. Susitna Dune 4 (HEA-508) lithic raw material types by component.

	Component 2				Component 3			
Raw Material	Debitage	Tools	Total	Local	Debitage	Tools	Total	Local
	n (%)	*n (%)*	*n (%)*	*%*	*n (%)*	*n (%)*	*n (%)*	*%*
Chert	-	-	-	-	65 (52.8)	5 (55.6)	70 (53.0)	1.4
Obsidian	-	-	-	-	2 (1.6)	-	2 (1.5)	0
Basalt	-	-	-	-	21 (17.1)	-	21 (15.9)	100
Rhyolite	-	-	-	-	3 (2.4)	1 (11.1)	4 (3.0)	0
Quartzite	-	-	-	-	1 (0.8)	-	1 (0.8)	100
Chalcedony	2 (100)	1 (100)	3 (100)	100	30 (24.4)	3 (33.3)	33 (25.0)	69.7
Granite	-	-	-	-	1 (0.8)	-	1 (0.8)	100
Total (%)	2 (100)	1 (100)	3 (100)	100	123 (100)	9 (100)	132 (100)	35.6

Table 31. Susitna Dune 4 (HEA-508) C3 artifact type by raw material class**.**

Artifact type	Chert	Obsidian	Basalt	Rhyolite	Quartzite	Chalcedony	Granite	Total
	n %	n %	n %	n %	n %	n %	n %	n %
Flake fragment	8 (12.3)	1 (50.0)	2 (9.5)	-	-	5 (16.7)	-	16 (13.0)
Flake	3 (4.6)	-	-	2 (66.7)	-	3 (10.0)	-	8 (6.5)
Primary cortical spall	-	-	-	-	-	1 (3.3)	-	1 (0.8)
Secondary cortical spall	-	-	-	-	1 (100)	-	-	1 (0.8)
Retouch chip fragment	24 (36.9)	-	10 (47.6)	1 (33.3)	-	6 (20.0)	-	41 (33.3)
Retouch chip	26 (40.0)	1 (50.0)	3 (14.3)	-	-	11 (36.7)	-	41 (33.3)
Biface thinning flake	4 (6.2)	-	6 (28.6)	-	-	4 (13.3)	1 (100)	15 (12.2)
Debitage subtotal	*65*	*2*	*21*	*3*	*1*	*30*	*1*	*123*
Hafted bifacial knife	-	-	-	-	-	1 (33.3)	-	1 (11.1)
Retouched flake fragment	1 (20)	-	-	1 (100)	-	1 (66.7)	-	4 (44.4)
Retouched flake	4 (80)	-	-	-	-	1	-	4 (44.4)
Tool subtotal	*5*	-	-	*1*	-	*3*	-	*9*
Formal:informal	0:5 0	-	-	0:1 0	-	1:2 0.5	-	1:8 0.1
Complete: broken	4:1 4	-	-	0:1 0	-	2:1 2	-	6:3 2
Mean complete tool weight	0.3	-	-	-	-	19.5	-	6.7
Tool:debitage	0.07	-	-	0.33	-	0.1	-	0.07

small, and few cases of medium and large size classes (Figure 53). Platform types for all proximal flakes in the C3 assemblage are primarily complex, with lesser amounts of smooth and few crushed platform types (Figure 54). Platform types on very small and small proximal debitage are primarily complex, with lesser amounts of smooth and crushed. Platform types on the single medium and large proximal debitage pieces are smooth and complex, respectively (Figure 55).

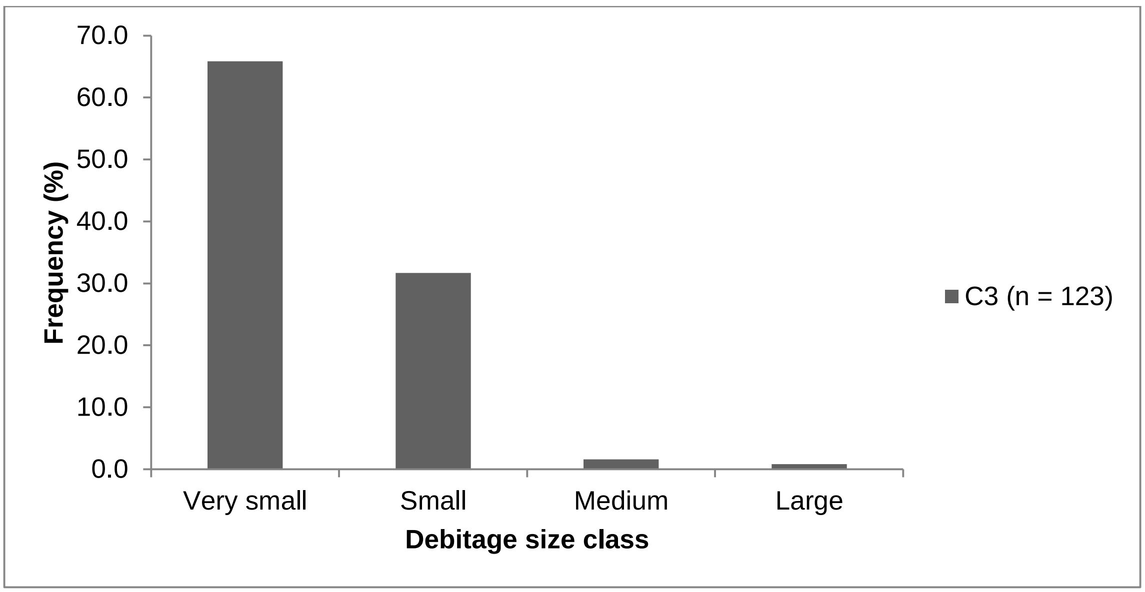

Figure 53. Debitage size class for Susitna Dune 4 C3.

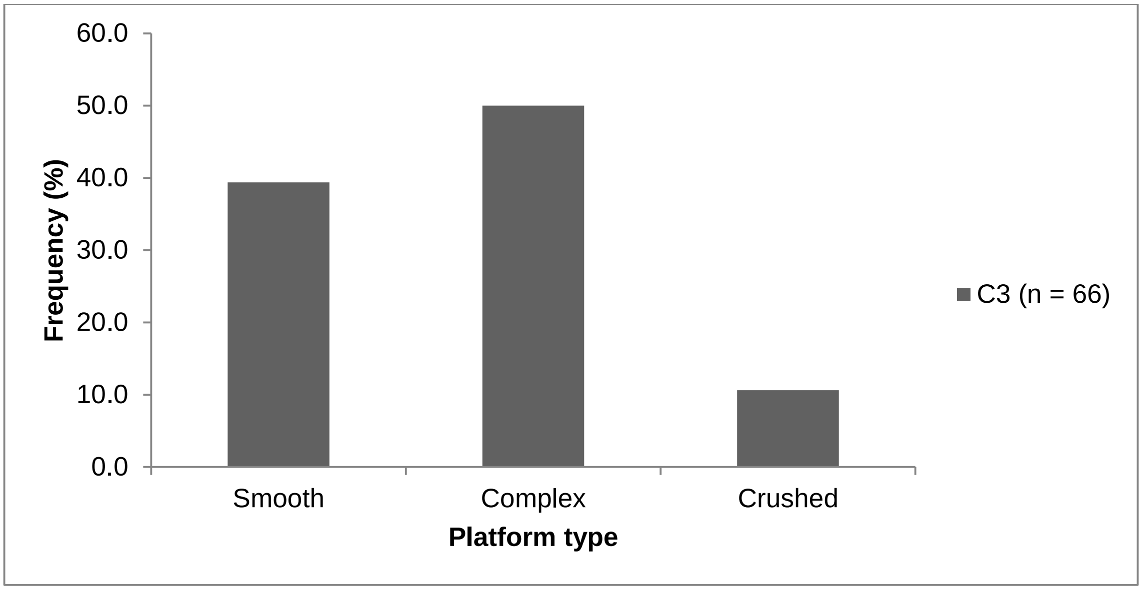

Figure 54. Platform types for all proximal debitage in the Susitna Dune 4 C3 assemblage.

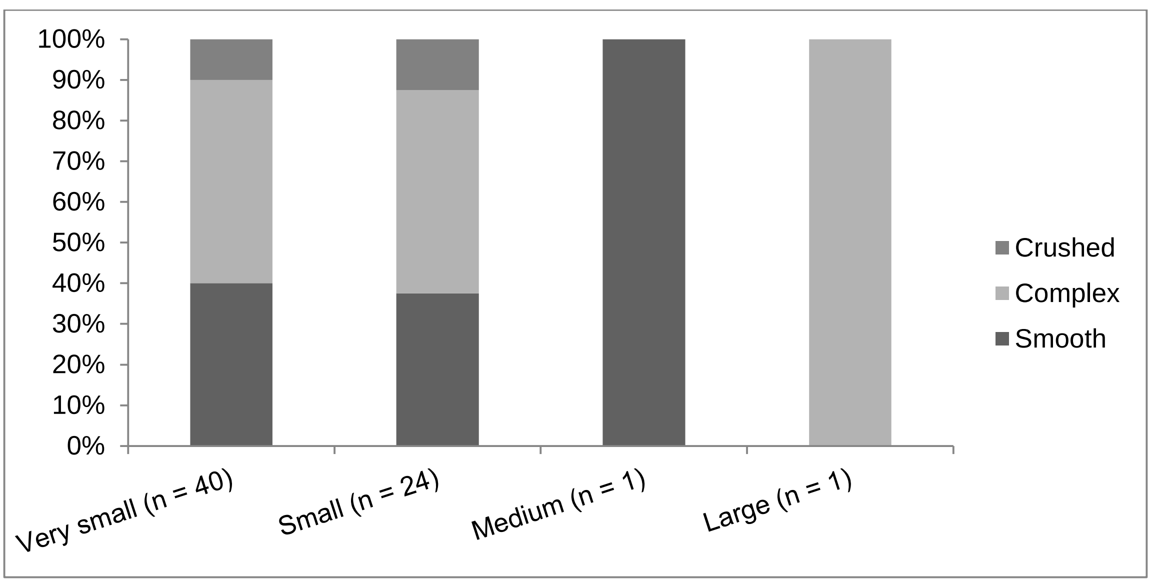

Figure 55. Platform type by size class for Susitna Dune 4 C3**.**

There are nine tools in the C3 assemblage, primarily retouched flakes (n = 9, 88.9%), but also one hafted bifacial knife (Table 31, Figure 56). The most common tool blank types are flake and biface thinning flake, and there is one bladelet tool blank (Figure 57). Tools in the C3 assemblage are primarily complete and have a relatively heavy mean weight of 6.7 g, but this is skewed by the hafted bifacial knife, which weighs 33.1 g. Tool forms are primarily informal, and tools are primarily made on chert, with lesser amounts of chalcedony and one rhyolite tool (Table 30). None of the tools in the C3 assemblage bear cortex. Chalcedony (76.5%) and rhyolite (75.0%) tools were retouched on the most available tool edge units, while chert tools (24.4%) were retouched on fewer margins (Table 17). The rhyolite tool has a high retouch index of 1.0, while chalcedony tools have a retouch index of 0.41, and chert a retouch index of 0.11 (Table 18).

Figure 56. Lithic tools from Susitna Dune 4 C3 assemblage. Top row: hafted bifacial knife, retouched flake; bottom row: retouched flakes.

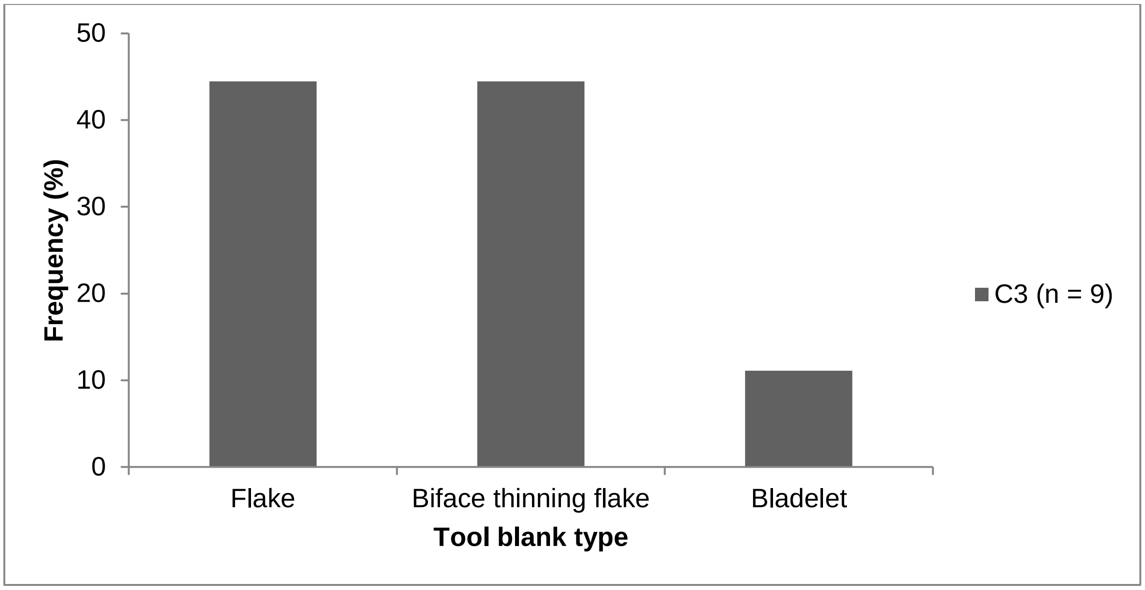

Figure 57. Tool blank type for Susitna Dune 4 C3.

Lithic raw material procurement. Just 35.4% of lithics in the Susitna Dune 4 C3 assemblage were made on lithic raw material types collected during our raw material survey (Table 30). There is considerable diversity within raw material classes, especially considering the rather small size of the assemblage. There are seven types of chalcedony, five types of chert, three types of rhyolite, and one each types of obsidian, basalt, and granite. The assemblage is dominated by one type of chert in particular, a fine-grained medium dark gray (N4) to moderate olive brown (5Y 4/4) chert (47.7% of assemblage), and four of the five chert retouched flakes are made on this material. The chalcedony tools and made on two types of chalcedony that we did not collect during our raw material survey, but could easily be variations of material we did collect, especially given the amount of within-nodule variability in chalcedony collected during the lithic raw material survey. Both quartzite and chalcedony are represented by cortical debitage, supporting local procurement of these materials.

A small amount of the chert in the assemblage matches material collected during our raw material survey, but the majority of this material appears to have been carried into the study area. The chert lithic raw material that dominates the C3 assemblage was likely transported to the study area from a more distant source, as was the rhyolite and obsidian. The chalcedony, basalt, granite, and quartzite were likely procured locally. Thus, lithic raw material procurement during the C3 occupation of the site appears to be focused on non-local procurement of high quality chert, supplemented by locally available, poorer quality material.

Primary reduction. Primary reduction was a minor component of lithic technological activities at the site (21.1% of debitage assemblage). Primary reduction at the site is supported by the presence of flake fragments and cortical spalls. The overall small size of the debitage and the low frequencies of smooth platforms on small, medium and large debitage support limited primary reduction. There is no statistically significant difference in the number of primary versus secondary reduction of raw materials at the site ($\chi^2 = 2.107$, $df = 2$; $p = 0.3486$). There are no cores in the C3 assemblage to assess formality of core production/reduction. Tools are made on formal (biface thinning flake, bladelet) and informal (flake) tool blanks, suggesting a mix of both formal and informal core techniques. Interestingly, the four retouched flakes made on the medium dark gray (N4) to moderate olive brown (5Y 4/4) chert that is dominant in the assemblage are made on flake (1), biface thinning flake (2), and bladelet (1) tool blanks, suggesting that this material was reduced both informally and formally at Susitna Dune 4. There is no evidence for bipolar knapping or scavenging. These data suggest that primary reduction was a minor component of technological activities at Susitna Dune 4 during the C3 occupation.

Secondary reduction. Secondary reduction was a significant component of lithic technological activities during the C3 occupation of Susitna Dune 4 (78.9% of debitage assemblage). This is supported by the high frequency of retouch chips and fragments and the high frequency of very small debitage. Secondary reduction focused on biface production, supported by the high frequency of biface thinning flakes and complex platforms, especially on small debitage. The high frequency of retouch chips supports a focus on tool maintenance, and the frequency of complex and smooth platforms in very small debitage suggests that both bifacial and unifacial tools were maintained.

Tools in the C3 assemblage are primarily informal types and were discarded complete, suggesting expedient use and discard. Chert tools are all lightweight informal types, were not intensively retouched on many margins, and were discarded complete with moderate remaining utility. These data plus the relatively low chert tool-to-debitage ratio suggests that chert was reduced onsite into expedient tools that were minimally used, and then discarded. Some tools were retouched intensively, including the rhyolite retouched flake and chalcedony tools. Chalcedony and rhyolite have high tool to debitage ratios, suggesting that rhyolite and chalcedony tools may have been brought onsite in completed form. These data suggest that lithic activities during the C3 occupation focused on biface production, and maintenance of bifacial and unifacial tools. Tool production was focused on informal tool types, but some informal tool types were intensively maintained.

Ratekin (HEA-187)

The Ratekin site sits above treeline at approximately 1000 masl in a shrub-tundra setting in the southwestern Clearwater Mountains (Figure 23). Professional archaeological investigations at the site consisted solely of surface collection; there have been no documented test excavations (Skarland and Keim 1958). The site consists of a broad surface lithic, fire-cracked rock, and bone scatter consisting of at least 10 loci covering a 200 m x 400 m area. Several hearths, including some reportedly rock lined, have been documented eroding out of the shallow surface sediments at the site. In addition, four rock-wall caribou blinds have been documented. The largest concentrations of lithic artifacts are from a bench near the foot of the Clearwater Mountains, while the rock wall blinds are located on a bench higher up in elevation, overlooking a steep drainage cut in the mountainside (Skarland and Keim 1958).

The Ratekin site has been interpreted to represent an ambush hunting kill site because of the high number of projectile points recovered from the site and the hunting blinds (Skarland and Keim 1958). However, the hearth features and fire-cracked rock suggest that more permanent camps occurred there as well. Oral history associated with the site indicates that the location played an important part in the Ahtna Tanana war, and is known to the Ahtna as the Ratekin ambush site (Kari and Fall 2003). The dense surface artifact assemblages from Ratekin (including many notched Northern Archaic points) have been interpreted to primarily represent a MH occupation (Esdale 2008); this is supported by a radiocarbon date from a hearth feature at nearby Rockfall Pond (HEA-320) indicating human use of the landform in the MH (C. Holmes, personal communication 2013 – see Chapter III). However, there is ethnographic evidence for use of the site into historic times, so the surface assemblage probably represents a palimpsest of multiple periods. Skarland and Keim (1958) suggested as much, saying that the site likely represents multiple occupations over a broad period of time.

This study presents results of analysis of the surface collected assemblage described in Skarland and Keim (1958), but focuses only on tools, cores, and technical debitage in this collection. Although there are few details on the surface collection methodology in Skarland and Keim (1958), it is clear from the resulting assemblage that little effort was made to collect debitage at the site. Despite being an undated assemblage, there are aspects of the surface assemblage that can inform on middle Holocene technological organization in the study area. There are 37 notched bifaces in the Ratekin assemblage. Notched projectile points in Alaska typically date to 7000 to 3000 cal BP (Esdale 2008). Although the age range for notched projectile points is fairly broad, they are typically thought to represent an MH occupation. Because of this, these notched projectiles are discussed here as a representation of middle Holocene technological activities in the uplands.

Ratekin lithic assemblage. The lithic assemblage from Ratekin has seven classes of lithic raw material. The C1 lithic assemblage is predominantly basalt, chert, and rhyolite, with minor amounts of chalcedony, argillite, obsidian, and quartzite (Table 32). The technical debitage assemblage consists of a single bladelet core-trimming flake. There are 140 tools in the Ratekin assemblage, primarily hafted and unhafted bifaces, scrapers, and retouched flakes, but also knives, cobble tools, retouched blades, and a drill (Table 33). Tool blanks in the Ratekin assemblage are primarily flake, but there are several biface tool blanks and various other types represented in small numbers, including biface thinning flake, blade, blade-like flake, cortical spall, and cobble blanks (Figure 58).

The majority of tools in the Ratekin assemblage are formal tool types, and are complete; the mean weight score for complete tools suggests an overall heavy toolkit (Table 33). Tools are primarily made on basalt, chert, and rhyolite, with and various other raw materials represented in low frequencies (Table 33). Chalcedony and quartzite unifacial tools were retouched on 100% of available margins, argillite on 94.7%, chert on 88.3%, basalt on 87.2%, rhyolite on 79.7%, and obsidian on 70.0% (Table 17). Chalcedony tools have a mean retouch index of 0.77, rhyolite 0.73, chert and basalt 0.67, argillite 0.36, and obsidian 0.29 (Table 18).

Table 32. Ratekin (HEA-187) lithic raw material types by component.

Raw Material	Debitage *n (%)*	Tools/cores *n (%)*	Total *n (%)*
Chert	1 (100)	46 (31.7)	47 (32.2)
Obsidian	-	3 (2.1)	3 (2.1)
Basalt	-	48 (33.1)	48 (32.9)
Rhyolite	-	32 (22.1)	32 (21.9)
Quartzite	-	2 (1.4)	2 (1.4)
Chalcedony	-	10 (6.9)	10 (6.8)
Argillite	-	4 (2.8)	4 (2.7)
Total (%)	1	145	146

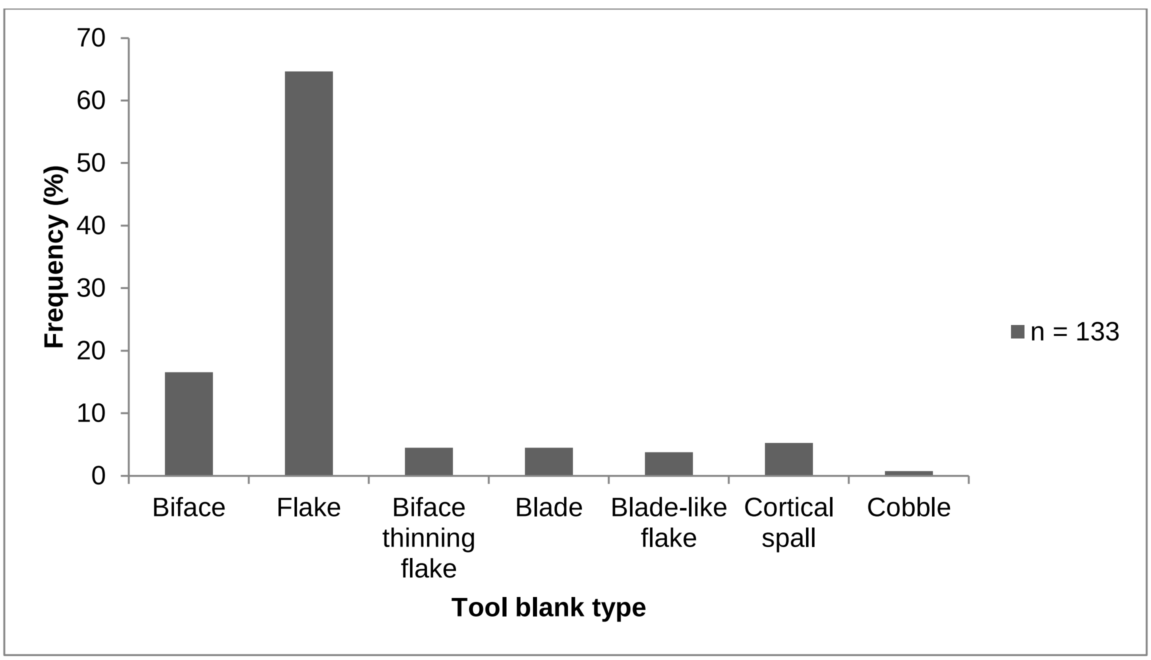

Figure 58. Tool blank types for tools in the Ratekin assemblage.

Table 33. Ratekin site (HEA-187) artifact type by raw material.

Artifact type	Chert n %	Obsidian n %	Basalt n %	Rhyolite n %	Quartzite n %	Chalcedony n %	Argillite n %	Total n %
Bladelet core trimming flake	1 (100)	-	-	-	-	-	-	1 (0.7)
Debitage subtotal	1	-	-	-	-	-	-	*1*
Hafted bifacial point	8 (18.6)	-	6 (12.8)	6 (18.8)	-	-	-	20 (14.3)
Hafted bifacial point fragment	9 (20.9)	1 (33.3)	12 (25.5)	6 (18.8)	-	2 (22.2)	1 (25.0)	31 (22.1)
Hafted bifacial knife	-	-	-	1 (3.1)	-	-	-	1 (0.7)
Hafted bifacial knife fragment	1 (2.3)	-	-	-	-	-	-	1 (0.7)
Middle stage biface	-	-	11 (23.4)	-	-	-	1 (25.0)	12 (8.6)
Middle stage biface fragment	1 (2.3)	-	2 (4.3)	-	1 (50)	-	-	4 (2.9)
Late stage biface	2 (4.7)	-	1 (2.1)	-	-	-	-	3 (2.1)
Late stage biface fragment	2 (4.7)	-	4 (8.5)	4 (12.5)	-	-	-	10 (7.1)
Finished biface fragment	-	1 (33.3)	-	2 (6.3)	-	-	-	3 (2.1)
Bifacial drill fragment	-	-	-	-	-	-	1 (25.0)	1 (0.7)
Retouched flake fragment	1 (2.3)	-	2 (4.3)	2 (6.3)	-	1 (11.1)	-	6 (4.3)
Retouched flake	2 (4.7)	1 (33.3)	3 (6.4)	3 (9.4)	-	-	-	9 (6.4)
End scraper on flake	7 (16.3)	-	1 (2.1)	5 (15.6)	-	1 (11.1)	-	14 (10.0)
End scraper on blade	1 (2.3)	-	-	-	-	-	-	1 (0.7)
End scraper fragment	2 (4.7)	-	-	1 (3.1)	-	1 (11.1)	-	4 (2.9)
Pan shaped end scraper	1 (2.3)	-	-	-	-	-	-	1 (0.7)
Steeply keeled end scraper	-	-	-	-	-	1 (11.1)	-	1 (0.7)
Steeply keeled end scraper fragment	1 (2.3)	-	-	-	-	-	-	1 (0.7)
Circular end scraper	-	-	-	1 (3.1)	-	-	-	1 (0.7)
Spurred end scraper	1 (2.3)	-	-	-	-	1 (11.1)	-	2 (1.4)
End and side scraper	1 (2.3)	-	1 (2.1)	-	-	1 (11.1)	-	3 (2.1)
Side scraper fragment	1 (2.3)	-	1 (2.1)	-	-	-	-	2 (1.4)
Single straight side scraper	1 (2.3)	-	1 (2.1)	1 (3.1)	-	-	-	3 (2.1)
Single-convex side scraper fragment	1 (2.3)	-	1 (2.1)	-	-	-	-	2 (1.4)
Chopping tool	-	-	1 (2.1)	-	1 (50)	-	-	2 (1.4)
Bilaterally retouched blade	-	-	-	-	-	-	1 (25.0)	1 (0.7)
Pointed retouched blade fragment	-	-	-	-	-	1 (11.1)	-	1 (0.7)
Tool subtotal	*43*	*3*	*47*	*32*	*2*	*9*	*4*	*140*
Simple flake core	-	-	-	-	-	1 (100)	-	1 (20.0)
Bipolar core	1 (33.3)	-	-	-	-	-	-	1 (20.0)
Multidirectional core	1 (33.3)	-	1 (100)	-	-	-	-	2 (40.0)
Bladelet/multidirectional core tool	1 (33.3)	-	-	-	-	-	-	1 (20.0)
Core subtotal	*3*	-	*1*	-	-	*1*	-	*5*
Formal:informal	40:3	2:1	41:6	27:5	1:1	7:2	3:1	121:19
	13.3	2	6.8	5.4	1	3.5	3	6.4
Complete:broken	24:19	1:2	24:23	17:15	1:1	4:5	1:3	72:68
	24	0.5	1.0	1.1	1	0.8	0.3	1.1
Mean complete tool weight	14.2	1.6	26.7	16.4	135.2	7.3	23.5	20.1

There are five cores in the C1 assemblage, one flake core, one bipolar core, two multidirectional cores, and one bladelet/multidirectional core. The flake core is made on chalcedony, has secondary cortex remaining on it, four platforms, two fronts, with an MLD of 36.29 and a weight of 12.3, for a size class score of 446. This specimen is a large cortical spall that was used as a flake core to produce numerous flakes. The bipolar core is made on chert, has no cortex, has an MLD of 40.43 and weighs 17.7 g, for a size class score of 716.

One multidirectional core is made on chert, has two platforms and two fronts, weighs 10.3 g and has an MLD of 30.25 for a size class score of 312; this piece is small, and has many stepped flake removals on it suggesting it was reduced intensively. One multidirectional core is made on basalt, has primary cortex remaining on it, has two platforms with cortical surfaces, two fronts, weighs 22.1 g and has an MLD of 45.65 for a size class score of 1009. The bladelet/ multidirectional core is made on chert, has no cortex, has three platforms and three fronts, weighs 12.0 g and has an MLD of 27.62 for a size class score of 331. This piece is small and battered, and appears to be a conical-type bladelet core that was recycled into a multidirectional flake core, and given the battering on the core edges, possibly even used as a tool.

Lithic raw material procurement. The lithic raw materials in the Ratekin assemblage were not directly compared to the material collected in our lithic raw material survey of the study area, but some inferences can be made by comparing physical descriptions of raw materials in the assemblage to material collected during our raw material survey. The Ratekin assemblage consists primarily of basalt, which is available in the study area, with almost equal amounts of chert, which we found very little of during our lithic raw material survey of the study area. Rhyolite, which we did not find during our survey, is well represented in the assemblage. Nineteen artifacts have cortex on them, six basalt (five with primary cortex, one with secondary), five rhyolite (one with secondary cortex, four with primary cortex), three chert (one with primary cortex, two with unknown cortex type), three chalcedony (one with secondary cortex, two with unknown cortex type), one quartzite with secondary cortex, and one argillite with primary cortex. Cortical data support local procurement of basalt and chalcedony, but interestingly there are many examples of non-local chert and rhyolite artifacts with cortex.

Two of the obsidian artifacts presented have undergone PXRF analysis, an obsidian retouched flake (AOD-12259) and an obsidian notched point (AOD-12258). Both of these are made on obsidian from the Wiki Peak source. Two additional obsidian artifacts from the site (not analyzed here) have been geochemically sourced; PXRF analysis of these two pieces indicates they come from the Batza Téna source (Table 19). In summary, the tool and core assemblages from Ratekin offer evidence for a focus on non-local raw material procurement, but also a significant amount of local procurement, and some long distance procurement.

Primary Reduction. Primary reduction activities at the site are inferred from core types and tool blank types. The majority of cores in the assemblage are informal; the one exception is the bladelet core, but this appears to have been recycled into a less formal flake core. Tool blank types also suggest an overall informal approach to core reduction and tool blank production. The sample size is small, but size class scores for the four cores described above indicate that the chert cores were discarded with less remaining utility than the basalt core, and there is evidence for bipolar knapping and recycling of chert cores in the assemblage. These characteristics suggest that chert was economized at the site. This assemblage data suggest an informal approach to core reduction and tool blank production at the Ratekin site, indicating expedient and non-economizing technological activities. Bipolar knapping and recycling suggest lithic raw material economization at Ratekin, and possibly raw material stress; however, there is no widespread evidence for scavenging in the assemblage, so this may have been in response to situational raw material shortages, possibly representing longer occupation time.

Secondary reduction. Tool forms in the assemblage have many specialized, formal forms, and are typically heavy. Chert tools in particular are made into formal types, and many of these were discarded complete. Rhyolite tools were made into formal types and discarded complete. Basalt tools were made into heavier formal types, and were also often discarded complete. While the single obsidian unifacial tool was retouched on 70% of edge units, it was surprisingly discarded with a high amount of remaining utility. The heaviest tool is a quartzite chopping tool weighing 135.2 g, which throws off the mean quartzite tool weight significantly. This tool was retouched on a high percentage of edge units, and discarded with moderate utility remaining. There is no statistically significant difference in the proportion of formal versus informal tool types made on local versus non-local raw material (as estimated above) ($\chi^2 = 0.621$, $df = 1$, $p = 0.4308$). This suggests there was no raw material selection for formal of informal tool types at the site.

Aside from the obsidian and quartzite tools described above, all of the tool types in the assemblage show retouch on a high percentage of tool edge units, and tools have an overall high retouch index, suggesting they were discarded with little utility remaining. There are many tools that were discarded complete, but this may be related to low remaining utility, not necessarily wasteful raw material use. Together these data suggest that formal, heavy tools were used at the site, and that most tools at the Ratekin site were intensively reduced and discarded with little remaining utility.

Ratekin notched point assemblage. The Ratekin assemblage presented here consists of 17 complete notched points and 20 notched point fragments (Figure 59). The assemblage has five classes of lithic raw material. Notched points are primarily made on basalt, with lesser amounts of chert and rhyolite, and minor amounts of obsidian and chalcedony (Table 34). Thirty-six of the 37 notched points were made on flake blanks (97.3%), the one exception being a notched point fragment with an unidentifiable blank type.

Figure 59. Sample of notched points from the Ratekin site.

Table 34. Ratekin (HEA-187) notched point assemblage.

Artifact type	Chert n %	Obsidian n %	Basalt n %	Rhyolite n %	Chalcedony n %	Total n %
Hafted notched biface	6 (54.4)	-	6 (40.0)	5 (55.6)	-	17 (45.9)
Hafted notched biface fragment	5 (45.5)	1 (100)	9 (60.0)	4 (44.4)	1 (100)	20 (54.1)
Total	*11*	*1*	*15*	*9*	*1*	*37*
Complete:broken ratio	6:5 1.2	0:1 0	6:9 0.7	5:4 1.25	0:1 0	17:20 0.9

Notched point lithic raw material procurement. The chalcedony notched point is made on a medium dark gray (N4) with dark gray (N3) mottled chalcedony, and the basalt notched points are made on a dark gray (N3) basalt, both of which are similar to raw materials collected in our raw material survey (representing 42.8% of raw materials in notched points). This material was collected in the Butte Creek drainage approximately 7 km southwest of the site. The chert and rhyolite in the assemblage do not match the description of raw materials collected during our raw material survey, so they are considered to be non-local. One of the rhyolite notched points from the Ratekin assemblage has been geochemically characterized using PXRF; it has been assigned to source group A (Coffman and Rasic 2015). The obsidian notched point had been geochemically characterized; PXRF data on this indicates it is from the Wiki Peak source approximately 340 km southeast of the site (Table19).

There is some diversity in the notched point assemblage: there are five types of chert, and one of each type of the remaining raw material classes. Chert notched points are primarily made on a fine-grained dark gray (N3) chert (n = 7, 63.6% of chert). The dominance of flake blanks in the notched point assemblage suggests they were part of an informal flake core reduction technological strategy. All of the notched bifaces have an irregular flaking pattern, and there is considerable variability in their form. Fracture types on notched points indicate that most were broken during use, then discarded (Figure 59). This sample includes the 20 hafted notched point fragments, as well as two that were essentially complete, but had their very tip removed (and are counted as complete in Table 23). In addition, many complete points were discarded. This suggests primarily use-related discard, with infrequent reworking after fracture. This suggests on overall informal technology, with no pressure to economize either local or non-local raw materials.

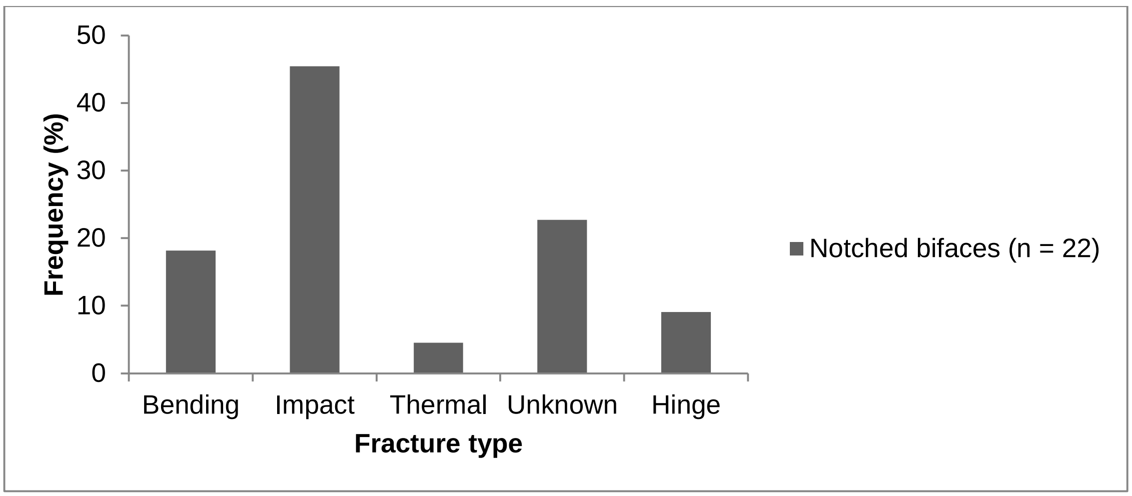

Figure 60. Notched point fracture types from the Ratekin site.

Butte Lake (HEA-189)

Butte Lake is a multi-component site situated on a prominent kame next to Butte Lake at approximately 1020 masl in the upper Susitna study area (Figure 23). The site is in a shrub-tundra setting with scattered spruce on the broader landscape (Wendt 2013). Butte Lake was initially excavated in 1984, and revisited in 2012 (Betts 1987; Wendt 2013). The 1984 investigation reported five cultural components at the site, an undated LP or EH component (CI), a middle Holocene component associated with standard radiocarbon dates of 6390 ± 580

^{14}C BP (Beta-10750) and 5030 ± 200 ^{14}C BP (Beta-10751) and assigned to the Northern Archaic tradition (CII), a late Holocene component associated with a standard radiocarbon date of 110 ± 60 ^{14}C BP (DIC-3068) and assigned to the Athabaskan tradition (CIII), a protohistoric component associated with a standard radiocarbon date of 180 ± 60 ^{14}C BP (DIC-3069) (CIV), and a historic component (CV) (Betts 1987).

In 2012 Wendt (2013) revisited the site and reworked the cultural chronology, finding additional material from the EH C1 (Betts CI) and MH C2 (Betts CII), but finding no evidence for separate Athabaskan tradition (Betts CIII) and protohistoric (Betts C IV) components, so he combined material from this context into a single LH component, C3. Wendt (2013) provided new AMS radiocarbon dates for the site, a hearth charcoal feature date of 4220 ± 30 ^{14}C BP (Beta-333870) associated with C2, and a hearth charcoal feature date of 410 ± 30 ^{14}C BP (Beta-333868) associated with C3. In addition, Wendt (2013) presents three radiocarbon dates on dispersed charcoal associated with C3: 160 ± 30 (Beta-334203), 540 ± 30 (Beta-334204), and 670 ± 30 (Beta-333869). Wendt (2013) considers the AMS dates on hearth feature charcoal from C2 and C3 to represent the true ages of these components. The 2012 investigations recovered an additional 212 lithics from C2, including two biface fragments, a scraper, a flake core, and a notched projectile point fragment. PXRF analysis of obsidian from material Betts (1987) recovered in CII indicates it was procured at the Wiki Peak source, but Wendt (2013) questions the context of this material and its association with C2. Wendt only recovered nine additional lithics from his C1, and did not find material to radiocarbon date this component.

Western Ahtna oral history indicates that Butte Lake was used as a fall camp, and that it served as a fall drive site where caribou were driven into the lake and dispatched from canoes (Betts 1987; Kari and Fall 2003). The LH artifact assemblage from the site supports this; faunal remains from the site consist primarily of caribou, with bird, fish and small mammal representing less than 1% of the faunal assemblage. The faunal assemblage suggests that during the historic occupation the site was a major caribou butchering/processing site (Wendt 2013). This study re-analyzed the lithic assemblages from the 1980's investigations; the 2012 assemblage was not available for analysis during the collections research phase of this study. This study excluded the protohistoric/historic material from 1984 components III, IV, and V, because these assemblages are associated with copper projectiles, indicating that lithic technology had been at least partially replaced with metal working technology during this occupation, making the lithic record potentially incomparable with prehistoric assemblages.

As reported in Wendt (2013), 48% (n = 487) of the artifacts recovered during the 1984 investigation could not be assigned to a component due to field methodological issues. The catalog on file at UAMN did not contain a record of the cultural component assigned to materials recovered during the 1984 excavations, so for the analysis presented here, cultural components were recreated by comparing stratigraphic information in the collections catalog with stratigraphic horizons associated with CI and CII in Betts' (1987) report.

This study presents lithic artifacts from CII (material clearly identified as being from features 1 and 22, stratum 3a, and the stratum 3a contact with stratum 4) and CI (material clearly identified as being from stratum 5 and the lower portion of stratum 4). This approach resulted in different total counts from CI and CII than those reported in Betts (1987). Betts reported 23 debitage and three tools in CI; this study analyzed nine debitage and two tools from CI. Betts reported 2 cores, 28 tools, and 234 debitage from CII, this study analyzed 1 core, 1 core tool, 32 tools, and 269 debitage in CII. The discrepancy in artifact counts can probably be explained by insufficient catalog information. An additional assemblage issue is that during the 1984 excavations, sediment was screened using 1/4" screen, while the assemblages recovered from the study area during the present study were screened using 1/8" screen. This probably led to a lithic sample biased towards larger debitage, and this is taken into consideration in the discussion. Despite these issues, the C1 and in particular the C2 assemblages from Butte Lake are of value for understanding MH and LH technological activities in the study area.

Component 1 lithic assemblage. The lithic assemblage from C1 is very small, consisting of nine debitage and two tools (Table 35). Debitage are primarily made on chert, with some basalt, rhyolite, and argillite. The two tools in the assemblage are a chert retouched blade fragment retouched on 66.7 of available edges, with a retouch index of 0.16, and a chert end scraper fragment made on a cortical spall with unknown cortex type, retouched on 37.5% of available edges with a retouch index of 0.79.

Component 2 lithic assemblage. The lithic assemblage from C2 consists of 269 debitage, 32 tools, one core/tool combination, and one core. The assemblage has nine classes of lithic raw material. The lithic assemblage is primarily chalcedony, with lesser amounts of chert, rhyolite, argillite, and basalt, and minor amounts of quartzite, obsidian, quartz, and unidentified material (other) (Table 35). The C2 debitage assemblage consists primarily of flake fragments, with lesser amounts of flakes, retouch chips, and biface thinning flakes, and minor amounts of retouch chip fragments, cortical spalls, burins, bladelets, microblades, and shatter. Technical debitage in the C2 assemblage includes two microblade core-trimming flakes (Table 36).

Table 35. Butte Lake (HEA-189) lithic raw material types by component.

	Component 1			Component 2		
Raw Material	Debitage *n (%)*	Tools/Cores *n (%)*	Total *n (%)*	Debitage *n (%)*	Tools/cores *n (%)*	Total *n (%)*
Chert	5 (55.6)	2 (100)	7 (63.6)	71 (26.4)	10 (29.4)	81 (26.7)
Obsidian	-	-	-	3 (1.1)	1 (2.9)	4 (1.3)
Basalt	1 (11.1)	-	1 (9.1)	13 (4.8)	6 (17.6)	19 (6.3)
Rhyolite	1 (11.1)	-	1 (9.1)	38 (14.1)	1 (2.9)	39 (12.9)
Quartzite	-	-	-	8 (3.0)	1 (2.9)	9 (3.0)
Chalcedony	-	-	-	106 (39.4)	14 (41.2)	120 (39.6)
Argillite	2 (22.2)	-	2 (18.2)	27 (10.0)	1 (2.9)	28 (9.2)
Quartz	-	-	-	1 (0.4)	-	1 (0.3)
Other	-	-	-	2 (0.7)	-	2 (0.7)
Total (%)	9	2	11	269	34	303

Table 36. Butte Lake (HEA-189) C2 artifact type by raw material.

Artifact type	Chert n %	Obsidian n %	Basalt n %	Rhyolite n %	Quartzite n %	Chalcedony n %	Argillite n %	Quartz n %	Other n %	Total n %
Flake fragment	20 (28.6)	-	-	15 (39.5)	-	42 (39.6)	17 (63.0)	-	-	94 (34.9)
Flake	18 (25.4)	1 (33.3)	3 (23.1)	5 (13.2)	3 (37.5)	13 (12.3)	9 (33.3)	-	-	52 (19.3)
Cortical spall fragment	1 (1.4)	-	-	-	-	3 (2.8)	-	-	-	4 (1.5)
Primary cortical spall	-	1 (33.3)	-	-	1 (12.5)	1 (0.9)	-	-	-	3 (1.1)
Secondary cortical spall	1 (1.4)	-	-	1 (2.6)	-	2 (1.9)	-	-	-	4 (1.5)
Retouch chip fragment	4 (5.6)	1 (33.3)	4 (30.8)	2 (5.3)	-	1 (0.9)	-	-	-	12 (4.5)
Retouch chip	12 (16.9)	-	5 (38.5)	5 (13.2)	2 (25.0)	22 (20.8)	-	1 (100)	-	47 (17.5)
Biface thinning flake	6 (8.5)	-	1 (7.7)	7 (18.4)	2 (25.0)	17 (16.0)	1 (3.7)	-	-	34 (12.6)
Shatter	-	-	-	-	-	-	-	-	2 (100)	2 (0.7)
Microblade core trimming flake	2 (2.8)	-	-	-	-	-	-	-	-	2 (0.7)
Bladelet fragment	-	-	-	-	-	2 (1.9)	-	-	-	2 (0.7)
Microblade	3 (4.2)	-	-	1 (2.6)	-	-	-	-	-	4 (1.5)
Microblade fragment	2 (2.8)	-	-	-	-	-	-	-	-	2 (0.7)
Burin spall	2 (2.8)	-	-	2 (5.3)	-	3 (2.8)	-	-	-	7 (2.6)
Debitage subtotal	71	3	13	38	8	106	27	1	2	269
Hafted bifacial point	-	-	1 (16.7)	-	-	-	-	-	-	1 (3.1)
Hafted bifacial chopping tool	-	-	1 (16.7)	-	-	-	-	-	-	1 (3.1)
Retouched flake fragment	7 (70.0)	1 (100)	2 (33.3)	1 (100)	1 (100)	3 (25.0)	-	-	-	15 (46.9)
Retouched flake	-	-	1 (16.7)	-	-	2 (16.7)	-	-	-	3 (9.4)
Retouched burin spall	-	-	-	-	-	1 (8.3)	-	-	-	1 (3.1)
Unilaterally retouched blade fragment	1 (10.0)	-	-	-	-	2 (16.7)	-	-	-	3 (9.4)
End scraper on flake	-	-	-	-	-	2 (16.7)	-	-	-	2 (6.3)
End scraper on flake fragment	-	-	-	-	-	2 (16.7)	-	-	-	2 (6.3)
Circular end scraper	-	-	1 (16.7)	-	-	-	-	-	-	1 (3.1)
Pan shaped end scraper/burin	1 (10.0)	-	-	-	-	-	-	-	-	1 (3.1)
End and side scraper	1 (10.0)	-	-	-	-	-	-	-	-	1 (3.1)
Multiple spurred graver fragment	-	-	-	-	-	-	1 (100)	-	-	1 (3.1)
Tool subtotal	*10*	*1*	*6*	*1*	*1*	*12*	*1*	-	-	*32*

Table 36. (Continued)

Artifact type	Chert n %	Obsidian n %	Basalt n %	Rhyolite n %	Quartzite n %	Chalcedony n %	Argillite n %	Quartz n %	Other n %	Total n %
Simple flake core	-	-	-	-	-	1 (50.0)	-	-	-	1 (0.4)
Microblade core/single spurred graver	-	-	-	-	-	1 (50.0)	-	-	-	1 (0.4)
Core subtotal	-	-	-	-	-	2	-	-	-	2
Formal:informal	2:8 0.25	0:1 0	3:3 1	0:1 0	0:1 0	4:8 0.5	1:0 -	-	-	10:22 0.5
Complete: broken	2:8 0.3	0:1 0	4:2 1	0:1 0	0:1 0	4:8 0.5	0:1 0	-	-	10:22 0.5
Mean complete tool weight	14.9	-	33.0	-	-	4.4	-	-	-	17.9
Tool:debitage	0.14	0.33	0.46	0.03	0.13	0.13	0.04	-	-	0.13

Debitage in the assemblage is primarily small, with lesser amounts of very small and medium debitage, and just two large debitage pieces (Figure 61). Platform types for all proximal flakes in the C2 assemblage are primarily crushed and smooth, with lesser amounts of complex and cortical surfaces (Figure 62). Platform types on very small debitage are primarily smooth, with lesser amounts of crushed and complex, and few lipped. Platform types on small and medium debitage are primarily crushed, with lesser amounts of smooth, complex, and lipped. The two large proximal debitage have one each smooth and complex platforms (Figure 63).

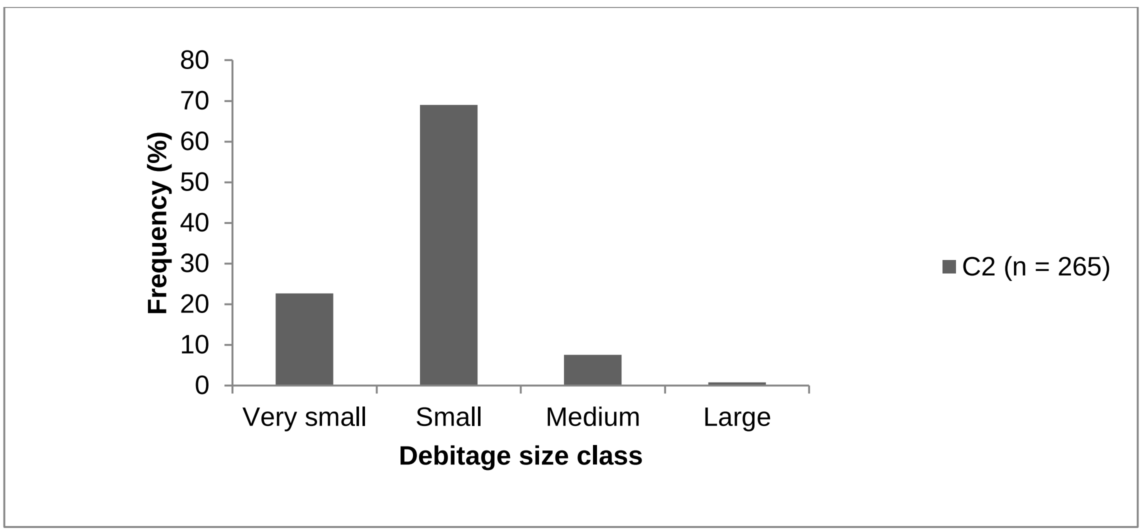

Figure 61. Debitage size for Butte Lake C2.

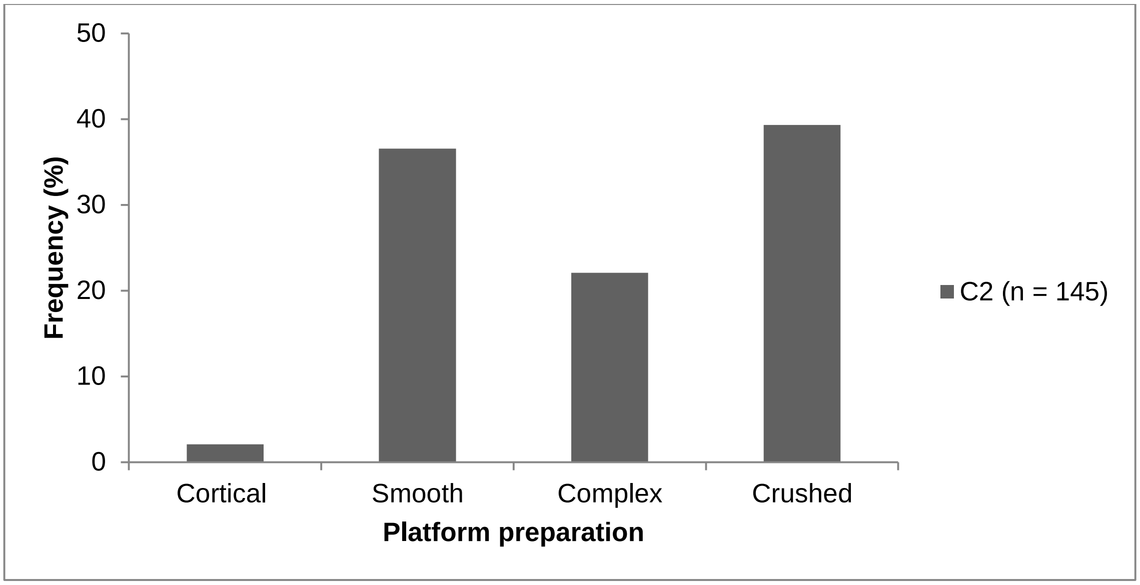

Figure 62. Proximal debitage platform for type for Butte Lake C2.

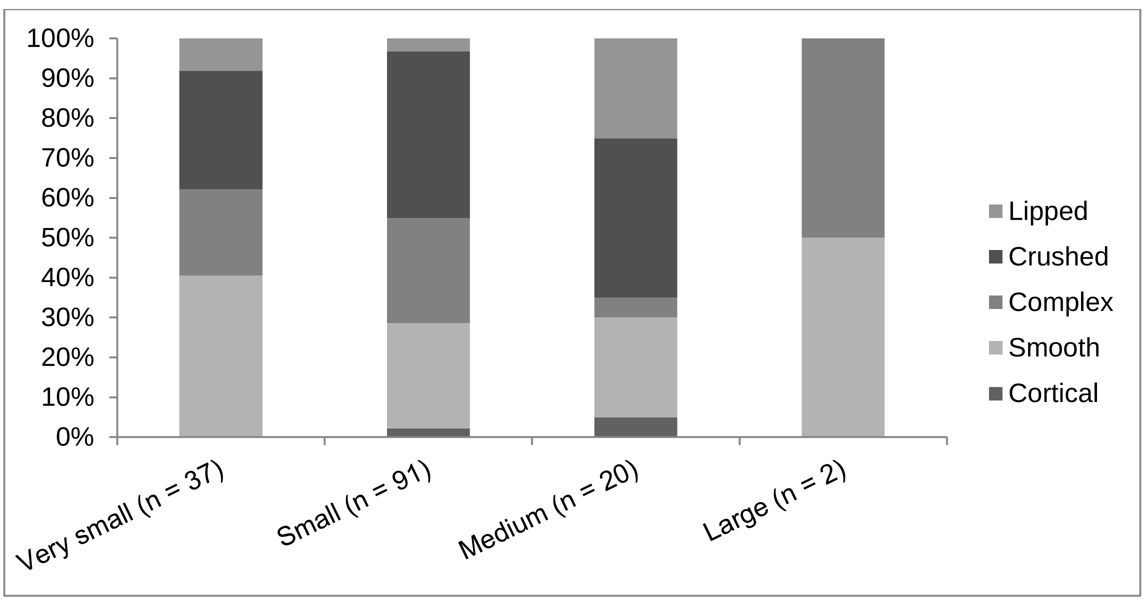

Figure 63. Proximal debitage platform type by size class for Butte Lake C2.

There are 33 tools in the C2 assemblage, primarily retouched flakes, but also end scrapers, bifaces, gravers, retouched blades, and a burin (Table 36). Tool blanks are primarily flake, but there are a variety of other blank types representing both formal and informal core reduction (Figure 64). Approximately one-third of the tools in the C2 assemblage are broken. Mean tool weight is fairly heavy, but this is affected by outliers and has a high standard deviation. Tool types are more informal, but there are many formal tool types, including some specialized scraper types (Table 36). Tools are primarily made on chalcedony, chert, and basalt (Table 35). Five tools bear cortex, including a chert retouched flake fragment with secondary cortex, a chert end and side scraper with primary cortex, a basalt hafted bifacial point with primary cortex, a basalt hafted chopping tool with secondary cortex, and a chalcedony end scraper on flake with primary cortex.

Basalt unifacial tools have been retouched on the most edge units, followed by chalcedony, chert, obsidian, and quartzite tools (Table 17). Likewise, basalt unifacial tools have the highest retouch index, followed by chalcedony, chert, rhyolite, and obsidian (Table 18). There are two cores in the assemblage, both made on chalcedony. There is one simple flake core fragment with three platforms, three core fronts, weighing 7.8 g and with an MLD of 41.66 mm, for a size class score of 325; this core has secondary cortex, and appears to have fractured along an inclusion during reduction. The second core is a complete microblade core with one faceted platform, one core front, weighing 2.7 g and with an MLD of 25.43 mm, for a size class score of 69; this core appears to have a small amount of cortex, but the type is indiscernible. This microblade core was made on a flake blank, and also has a single graver spur on the opposite end of the core face, classifying it as a core tool (Figure 65).

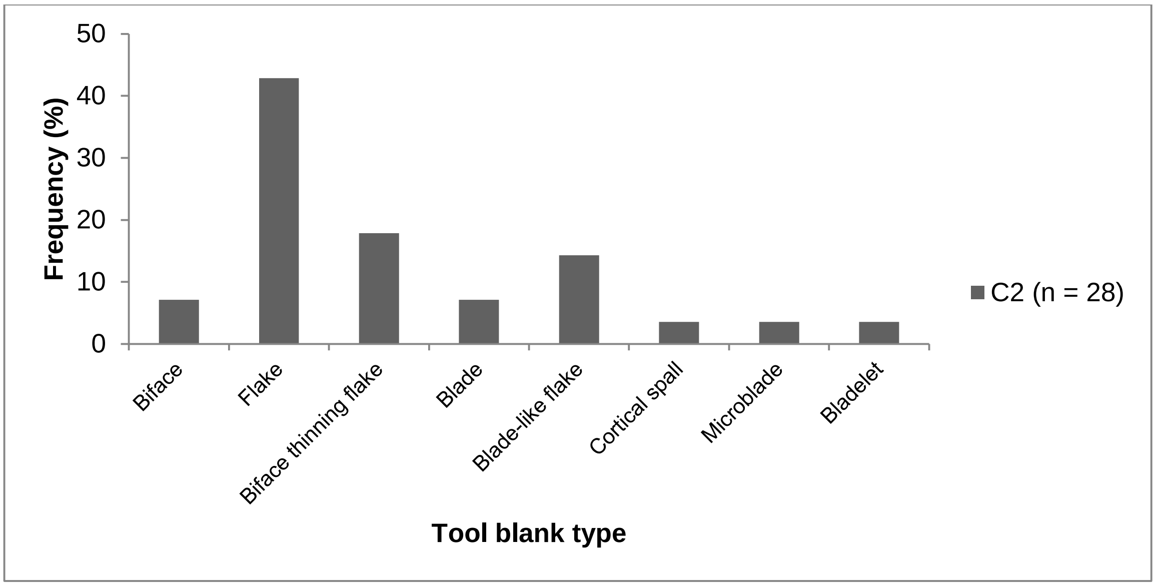

Figure 64. Tool blank type for Butte Lake C2.

Figure 65. Microblade core on flake blank with graver spur from Butte Lake C2.

Lithic raw material procurement. The lithic raw materials in the Butte Lake assemblage were not directly compared to the material collected in our lithic raw material survey of the study area, but inferences can be made by comparing physical descriptions to those of material collected during our raw material survey. There is considerable diversity in the raw materials at the site: there are

26 types of chalcedony, 21 types of chert, eight types of quartzite, seven types of rhyolite, three types each of obsidian and argillite, and one type each of basalt, quartz, and “other”. The most common raw material is a medium dark gray (N4) chalcedony (12% of assemblage), which matches the color and description of chalcedony we collected in the Butte Creek drainage 18 km southeast of the site, but is probably available closer to the site throughout the Butte Creek drainage. The next most common types are a very light gray (N8) rhyolite (7.8% of assemblage), a medium dark gray (N4) to medium gray (N5) banded chert (7.1% of assemblage), and a yellowish gray (5Y 8/1) argillite, the latter matching the description of argillite we collected in the Clearwater Mountains 32 km southeast of Butte Lake. We did not find the chert and rhyolite represented in the assemblage during our raw material survey. Based on this comparison, I assume that all chert, rhyolite, and obsidian in the C2 assemblage is non-local (40.9% of assemblage).

The most common cortical debitage is on chalcedony, which is expected given the local source; in addition there is cortical quartzite that was probably procured locally as well. Interestingly chert, obsidian, and rhyolite, all considered to be non-local raw materials, have debitage pieces that bear cortex in the assemblage. One obsidian core-reduction flake (AOD-12263), one obsidian cortical spall (AOD-12266), and the lone obsidian tool (AOD-12267) were geochemically characterized, PXRF analysis indicates these artifacts are all from the Wiki Peak source, 360 km southeast of the site (Table 19).

These data suggest that lithic raw material procurement at Butte Lake focused primarily on non-local procurement of chert and rhyolite, supplemented by local procurement of chalcedony, basalt, and argillite. Obsidian was transported long distances to the site; the presence of obsidian bearing cortex indicates this material traveled long distances in an unworked or only initially worked form.

Primary reduction. Primary reduction was a significant component of technological activities at Butte Lake (62.1% of debitage assemblage). Primary reduction is supported by the high frequency of flake fragments, flakes, and cortical debitage, and the number of smooth platforms on small and medium debitage. Most of the medium dark gray to medium gray banded chert described above was from the same provenience, and consisted of 21 pieces of debitage, including core-reduction flakes, flake fragments, and two cortical spalls with primary geologic cortex. This material appears to have been deposited during one flake-core reduction event, possibly from an unworked nodule of chert carried onto the site.

There are higher than expected counts of argillite and chert primary reduction debitage; the differences in proportions are significant ($\chi^2 = 26.151$, $df = 5$, $p < .0001$). This suggests that primary reduction focused on these materials. The high frequencies of argillite, chalcedony, rhyolite, and chert flake fragments suggest these materials were being reduced informally. Microblades and technical spalls indicate that formalized core reduction occurred, but that it was a minor component of technological activities. The microblade core made on a flake blank represents an informal approach to producing microblades. Core types, blank types, and debitage types indicate that both informal and formal core reduction occurred. There is no evidence for bipolar knapping or scavenging in the C2 assemblage.

Secondary reduction. Secondary reduction was a moderate component of lithic technological activities during the C2 occupation (37.9% of debitage assemblage). Secondary reduction is supported by the presence of retouch chips and fragments, and the presence of small and very small debitage. Biface production appears to be a significant component of secondary reduction, supported by the high frequency of biface thinning flakes, and the relatively high frequency of complex platforms on small debitage. Tool maintenance focused on uniface retouch, supported by the frequency of smooth platforms on very small debitage. There are higher than expected counts of basalt, chalcedony, and rhyolite secondary debitage, suggesting that secondary reduction activities focused on these materials; the differences in proportions are significant ($\chi^2 = 26.151$, $df = 5$, $p < .0001$).

Tools in the C2 assemblage are primarily informal types, and are heavy, but there are several examples of formal, specialized tools. Basalt and chalcedony raw materials have the highest ratio of formal to informal tools; tools on these raw materials also have a moderate retouch index, and a high percentage of retouched edge units. These data suggest that locally available basalt and chalcedony were made into formal tools that were heavily maintained, but often discarded with moderate utility remaining. Basalt and chalcedony have the highest ratio of complete to broken tools, supporting the idea that basalt and chalcedony tools were commonly discarded with remaining utility. Non-local chert was made into informal tool forms that have moderate edge unit retouch and moderate retouch index scores, and apparently were less intensively maintained than chalcedony and basalt tools. Chert tools were more likely to be discarded broken.

Overall, tools were discarded both broken and complete, suggesting some non-economizing raw material use, but many unifacial tools were reduced relatively intensively. Tools were primarily made on non-local raw material; interestingly, locally available raw materials were reduced the most intensively. In addition, tool burination was a minor component of secondary reduction, including one pan-shaped end scraper that had the working face burinated off prior to being discarded. These data suggest that secondary reduction focused on biface production and unifacial tool maintenance, with maintenance focused on both formal and informal tool types. Tool production focused on using local raw material to make formal tools that were intensively maintained, but sometimes discarded complete and with remaining utility.

Discussion

Most of the lithic assemblages presented here are from archaeological sites that have been only initially tested, so that in some cases they potentially represent a relatively small portion of the total site area and activities carried out there in prehistory. Further excavations at these sites could reveal more diversity in the lithic assemblages, as assemblage diversity is strongly correlated with sample size (Kintigh 1984), and archaeological deposits are often spatially variable (Binford 1978). Despite these caveats, this study works under the assumption that the assemblages presented here provide a reasonably accurate picture of lithic technological activities conducted at these sites. The episodic depositional sequences in the study area may have resulted in palimpsest assemblages representing repeated site use over hundreds or thousands of years. The high frequencies of different lithic raw material types in most of the assemblages suggest multiple occupations are represented in each component. For this reason, this study looks at general, long-term trends in lithic technological organization and landscape use, using broad time periods of early, middle and late Holocene, because higher-resolution research questions require higher-resolution data then is available presently.

Despite evidence for palimpsest deposits, the data from the study area are still useful for interpreting changes in subsistence and settlement systems over time. In fact, palimpsest archaeological deposits have been shown to be better suited for assessing human behavioral response to long-term ecological change, or more specifically “a series of time-averaged palimpsests, each spanning decades or even centuries, may better show trends of social and behavioral change than an equivalent number of single-occupation snapshots” (Barton and Riel-Salvatore 2014).

Defining technology and landscape use over these broad time periods is still useful for the research questions stated at the outset, but there was surely more variability in lithic technological organization and corresponding landscape use over shorter time scales that cannot be identified with these assemblages. This study is not an exhaustive assessment of upland landscape use; it probably does not capture all aspects of landscape use in the study area. However, it likely captures a significant component of upland subsistence activities in the study area, so settlement-organization and landscape-use interpretations derived from these data are a meaningful contribution to our still-developing understanding of prehistoric landscape use in interior Alaska. Here I use toolstone procurement, primary reduction, secondary reduction, and tool production and discard data from the upper Susitna lithic assemblages to reconstruct lithic technological organization in the EH, MH, and LH periods.

Early Holocene Lithic Technological Organization in the Upper Susitna Basin

There is just one significant assemblage that can be used to characterize EH lithic technological organization in the study area, the C1 assemblage from

Susitna River 3 (10,690-10,300 cal BP) (Table 26). The C1 lithic assemblage has a high percentage of non-local lithic raw materials. Lithic raw materials are primarily high-quality chert, presumably procured from at least two source locations. There is no evidence for long-distance transport of obsidian. Locally available lithic raw material was used to supplement lithic technological activities during this occupation, primarily poorer-quality chalcedony available within 13 km of the site. There is very little cortical debitage, all on locally available chalcedony, suggesting that initial reduction of all raw materials occurred elsewhere, and raw materials entered the site as highly reduced tools and/or cores.

Primary reduction was a minor component of lithic reduction activities at Susitna River 3, and it focused on informally reducing locally-available chalcedony, and minor amounts of non-local chert. There are no cores in the assemblage, suggesting that raw materials carried onto the site in core form were carried away, and not discarded onsite. Tools were made on both informal and formal flake blanks, including bladelet, microblade, and biface thinning flake blanks, suggesting that formally prepared cores, mostly made on chert, were carried onto the site, reduced, and carried away. These assemblage attributes suggest raw material economization.

Table 37. Assemblage characteristics for sites in the upper Susitna study area.

	Early Holocene	Middle Holocene			Late Holocene				Undated	
	Susitna River 3 C1	Susitna River 3 C2	Butte Creek 1 C1	Butte Lake C2	Susitna Dune 1 C3	Susitna River 3 C3	Alpine Creek 8 C1	Susitna Dune 4 C3	Windy Creek 1 C1	Ratekin
Toolstone procurement										
Local	36%	59%	72%	59%[2]	60%	74%	94%	35%	98%	44%[2]
Non-local	64%	41%	28%	41%[2]	40%	26%	6%	65%	2%	56%[2]
Long distance (obsidian)	N	L	L	L	L	L	N	L	L	L
Cortical debitage/tools	0.004%	0.01%	0.02%	0.05%	0.01%	0.01%	0.01%	0.02%	0.04%	0.13%
Primary reduction										
Primary reduction debitage	28%	38%	34%	62%	24%	37%	58%	21%	61%	na
Formal:informal core ratio	N	N	0:1	0:2	N	N	0:1	N	N	0:5
Technical debitage	N	L	N	L	N	L	N	N	N	L
Formal tool blank	41%	32%	13%	40%	50%[1]	18%	11%	55%	40%[1]	27%
Bipolar knapping, tool recycling/scavenging	L	L	N	N	N	L	N	N	N	L
Secondary reduction, tool production and use										
Secondary reduction debitage	72%	62%	66%	38%	76%	63%	42%	79%	39%	na
Formal:informal tool ratio	7:26 0.3	17:50 0.3	8:9 0.9	10:22 0.5	0:2[1] 0	9:18 0.5	3:6 0.5	2:3 0.7	2:3 0.7	121:19 6.4
Mean retouched edge unit	51%	52%	60%	73%	30%[1]	55%	57%	43%	62%	88%
Mean retouch index	0.51	0.37	0.40	0.50	0.10[1]	0.37	0.20	0.25	0.30	0.69
Tool:debitage ratio	0.05	0.02	0.02	0.13	0.01	0.02	0.01	0.07	0.02	-
Complete:broken tool ratio	11:22 0.5	27:40 0.7	7:10 0.7	10:22 0.5	1:0 1[1]	5:22 0.3	2:7 0.2	0:5 0	0:5 0	72:68 1.1
Raw material selection	Y	Y	Y	Y	No[1]	Y	Y	No	No	No
Focus on biface (B) or microblade (M) technology	B	B	B	B	B	B	B	B	B	B
Inferred mobility	H	L	L	L	L	L	L	H	L	H & L

N: 0%; L: low (≤ 33%); M: medium (34-66%); H: high (≥67%); Y: yes; No: no.
[1] small sample size
[2] estimated

Secondary reduction was the dominant technological activity at Susitna River 3, and focused on unifacial tool maintenance, with lesser amounts of biface production. The C1 toolkit is lightweight, consisting mostly of informal retouched flakes made on non-local, high quality cherts. In addition there are burins, a formal, specialized tool type typically associated with bone or woodworking. There are no bifaces in the C1 assemblage, although debitage indicates that some biface production and maintenance occurred.

Tools in the C1 assemblage show overall moderate amounts of edge retouch, and tools were discarded with moderate remaining utility. Non-local chert tools were more intensively reduced than local chalcedony tools. The frequency of burin spalls in the assemblage suggests that burins made on non-local chert were heavily retouched. Many chert burin spalls exhibit retouch, and chert tools were primarily discarded broken. Tool to debitage ratio is higher than most other components in the study area. There is raw material selection occurring at the site; primary reduction focused on locally available raw materials and non-local rhyolite, while secondary reduction focused on non-local, high quality cherts, suggesting economization of non-local chert. Site density is relatively low for Susitna River 3 C1, and the site is situated on a prominent overlook in the study area.

There is one additional component in the study area dating to the EH (Susitna Dune 1 C1), and one undated component thought to date to the EH (Butte Lake C1), but the assemblages from these sites are very small. Susitna

Dune 1 C1 is associated with an EH age of (11,170-10,770 cal BP). The meager lithic assemblages from Susitna Dune C1 suggest that locally available argillite and chalcedony were reduced, but with such a small sample, it may be misleading to make too much of this.

The Butte Lake C1 debitage assemblage is hypothesized to date to the EH based on stratigraphic position. The lithic assemblage from C1 suggests that non-local chert and rhyolite and locally available basalt and argillite were reduced during this occupation. The two chert tools in the assemblage are made on what appears to be non-local chert, although one tool bears cortex, and may represent an unreduced chert core or finished tool carried into the study area. Chert tools exhibit retouch on a moderate percentage of edge units, and were discarded with a moderate amount of utility remaining. There is evidence for formal core reduction in the retouched blade, and despite being made on an informal cortical spall blank, the end scraper on flake represents a formal tool type. These assemblage attributes provide a mixed signal of formal, economized technology and informal, non-economized technology, no doubt due to the small assemblage size. Still, the two non-local chert tools suggest quality raw material was transported into the study area, minimally in the form of finished tools, but possibly as a formally prepared blade core.

Despite the fact that there is just one significant EH lithic assemblage, there are patterns in this assemblage that can be used to infer EH mobility and provisioning strategies. The Susitna River 3 C1 assemblage meets several expectations of high mobility (Table 12), in that lithic raw material procurement is focused on high-quality, non-local material, there is evidence of economization of non-local raw material, few artifacts bear cortex, lithic technological activities are focused on tool maintenance, there is a relatively high tool to debitage ratio, there is raw material selection evident in the assemblage, tools are lightweight, and are both multipurpose (retouched flakes) and specialized (retouched bladelets, burins), there is low artifact density, and no fire-cracked rock.

However, there are aspects of the assemblage that do not fit with a high mobility pattern. There is no long-distance transport of obsidian. Tool blank data suggest that both formal and informal cores were reduced onsite, but there is no technical debitage representing formal core reduction and maintenance. Tools in the assemblage are primarily informal types, and only moderately retouched. Complete tools were relatively frequently discarded onsite.

Taken together, the lithic technological characteristics of Susitna River 3 C1 suggest that this site represents a shorter-term camp occupied by a mobile group, moving through the study area provisioned with the lithic raw material necessary for subsistence activities, creating small, lightweight, informal tools and functionally specific tools on the material they carried with them, as well as informal tools on locally available lithic raw material that had minimal transport cost so there was no need to maximize utility. There are indications of a formalized, economized technology, but a significant portion of the technology was also informal, possibly to maintain flexibility in the toolkit. The possible bone and/or woodworking burins in the assemblage suggest these materials may have been incorporated with lithic technology into a complex gear system.

The preparation apparent in carrying high-quality lithic raw material in formal cores may be due to uncertainty about raw material resources in the study area, or knowledge that raw material resources in the study area were poor. It could be that formal cores and tools were maintained onsite and carried away, while informal tools were moderately retouched, and discarded onsite. This would explain the apparent informal aspects of the lithic technology, but cannot be proven with the current dataset. Another possibility is that access to locally available lithic raw materials, despite the overall poor quality, relaxed some of the demand for economization of lithic raw material carried into the study area.

Does the C1 assemblage at Susitna River 3 represent a residential forager camp, or a long-distance logistical camp? A comparison of tool richness for all sites in the study area (Figure 66) indicates that Susitna River 3 C1 (SR3 C1) tool richness is at the expected level when compared to other sites in the study area. However, much of this diversity can be attributed to the variety of tool blanks that were used as informal retouched flakes. Artifact density is

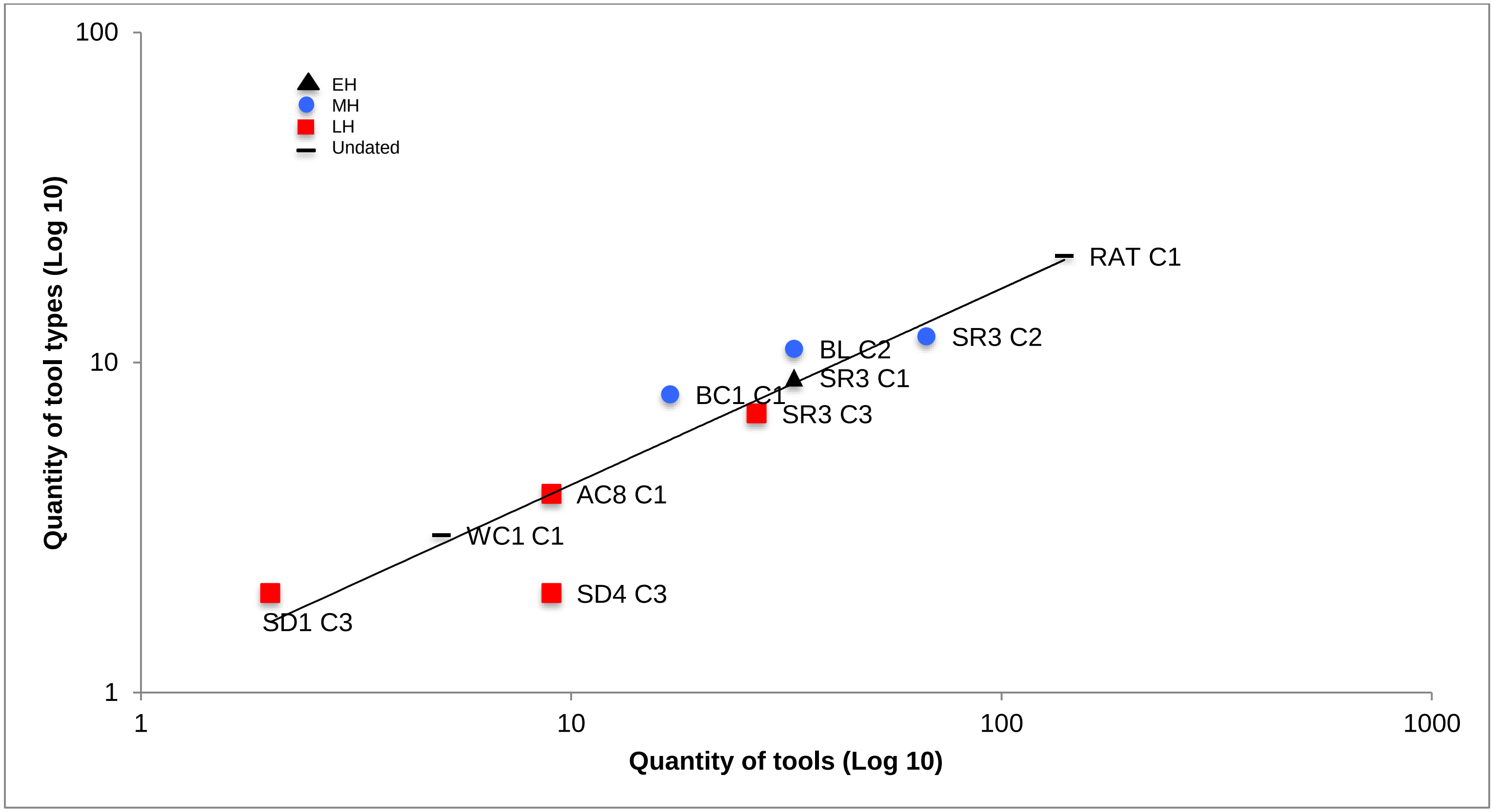

Figure 66. Tool richness for important sites in the upper Susitna study area. See text for explanation of abbreviations.

relatively low in Susitna River 3 C1, and there is very little primary reduction, suggesting a shorter-term camp. The informally produced retouched bladelet tools appear to have been produced for a single purpose, and not designed for long use-life and multiple functions. The presence of burins and tiny retouched bladelets and burin spalls in the toolkit suggests specialized activity at the site. Taken together, these data support Susitna River 3 C1 representing a long-distance logistical camp.

Middle Holocene Lithic Technological Organization in the Upper Susitna Basin

There are three components that can be used to characterize MH lithic technological organization, Susitna River 3 C2 (5711-3984 cal BP), Butte Creek 1 C1 (4867-4432 cal BP), and Butte Lake C2 (6272-4645 cal BP) (Table 37). Raw material procurement during the MH focused on locally available material, but also included moderate amounts of non-local procurement, and some long distance movement. There is variability in the proportions of local versus non-local raw material procurement between MH components (Figure 67); these differences are statistically significant ($\chi^2 = 44.388$; $df = 2$; $p < 0.0001$), indicating inter-site variability in raw material procurement. In Butte Lake C2 and Susitna River 3 C2 there are higher than expected counts of non-local material, while in Butte Creek 1 C1 there are higher than expected counts of local material.

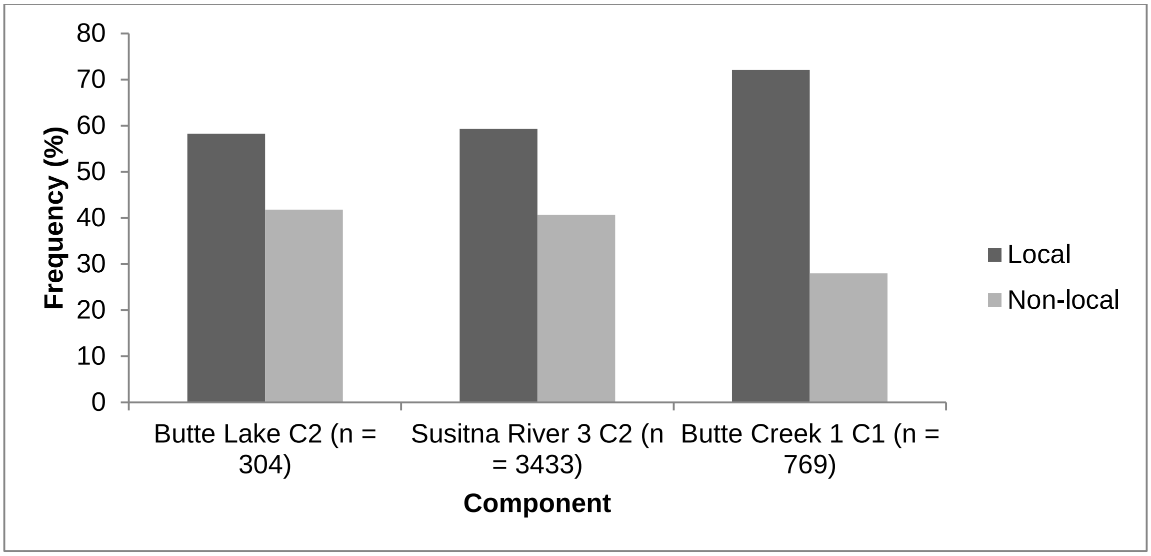

Figure 67. Local versus non-local lithic raw material procurement comparison for middle Holocene components.

In Butte Lake C2, raw material assumed to be non-local makes up 41% of the assemblage, but the chert and rhyolite that comprise to majority of this material are represented at the site by cortical debitage, suggesting that this material was carried to the site in an unreduced state, then reduced onsite. This is very evident in the flaking debris described above representing reduction of a single chert nodule with primary cortex. A comparison of debitage size between MH components shows that debitage in Susitna River 3 C2 and Butte Creek 1 C1 are predominantly very small, while debitage in Butte Lake C2 are predominantly small, with a relatively high proportion of medium debitage as well (Figure 68). Debitage size data suggest more primary reduction occurred in Butte Lake C2 than the other assemblages; however, these data are surely affected by the fact that the 1984 excavations at Butte Lake used 1/4” screen, while the fieldwork that produced the rest of the assemblages in this study used 1/8” screen. This would have reduced the number of debitage in the very small category recovered in Butte Lake C2. Butte Creek 1 C1 has the highest frequency of very small debitage, indicating that secondary tool maintenance occurred here more than at the other MH sites.

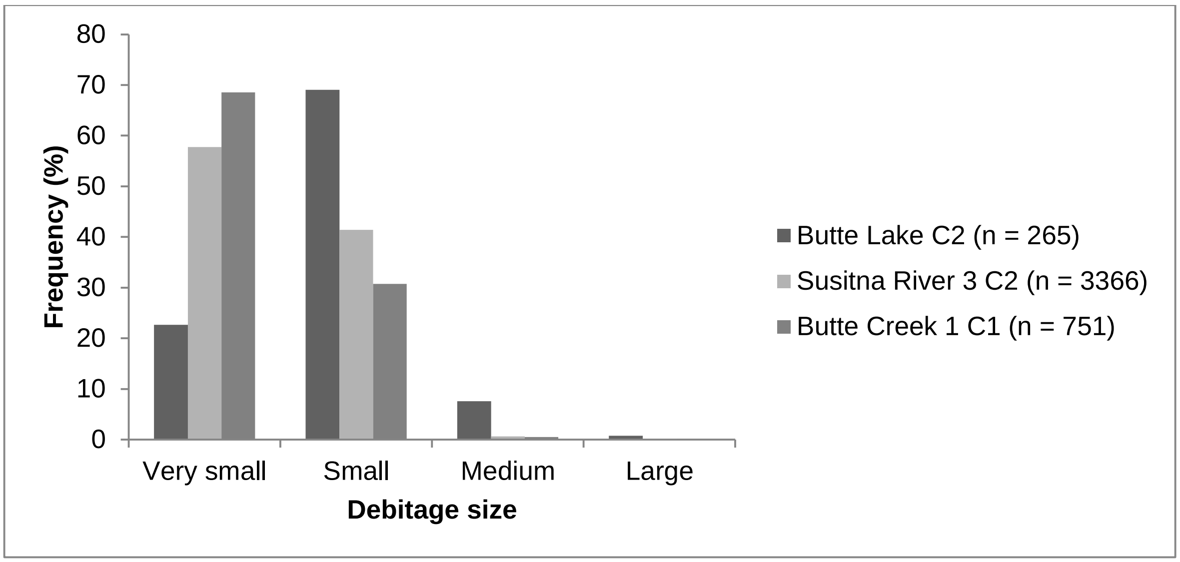

Figure 68. Debitage size class comparison between middle Holocene components.

A higher frequency of primary reduction in Butte Lake C2 is supported by a comparison of debitage classes between components (Figure 69). There are significant differences in the proportions of primary and secondary debitage types between MH components ($\chi^2 = 69.593$; $df = 2$; $p < 0.0001$), indicating there is inter-site variability in reduction type. In Butte Lake C2 there are higher than expected counts of primary reduction debitage, while at Susitna River 3 C2 and

Butte Lake C1 there are higher than expected counts of secondary reduction debitage. There are more core reduction flakes, flake fragments and cortical debitage in Butte Lake C2, and more retouch chips in Susitna River 3 C2 and Butte Creek C1. The presence of more primary reduction debitage in Butte Lake C2 suggests that debitage size in the assemblage may not have been skewed significantly by different field sampling strategies. The frequency of biface thinning flakes in the Butte Lake C2 assemblage suggests that biface production occurred more here than at the other sites.

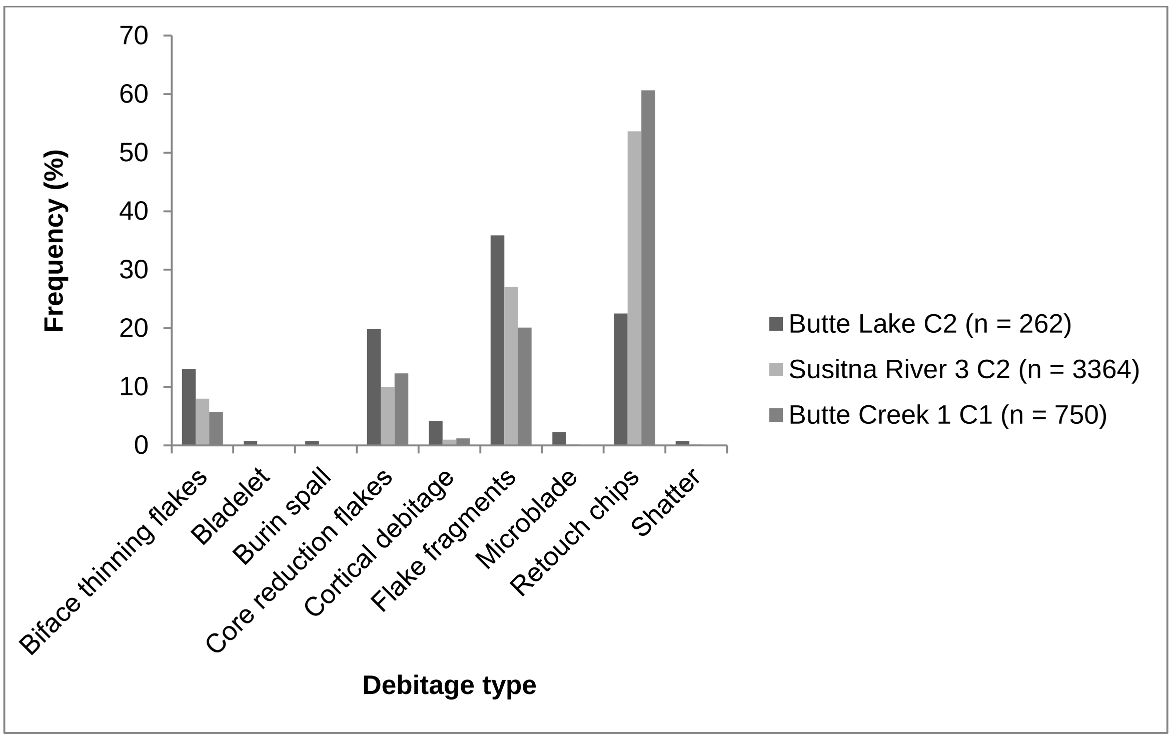

Figure 69. Debitage class comparison between middle Holocene components.

Platform types (Figure 70) in the Butte Lake C2 assemblage are primarily crushed, perhaps indicating less-controlled reduction of informal flake cores, but possibly relating to the overall poor quality of locally available lithic raw material reduced at the site. Platform types in the Susitna River 3 C2 assemblage are mostly smooth, and as described above, many of these are very small in size, suggesting that they are the result of retouching unifacial tools. Complex platforms are also well represented in the Susitna River 3 C2 assemblage, indicating secondary reduction and maintenance of bifacial tools.

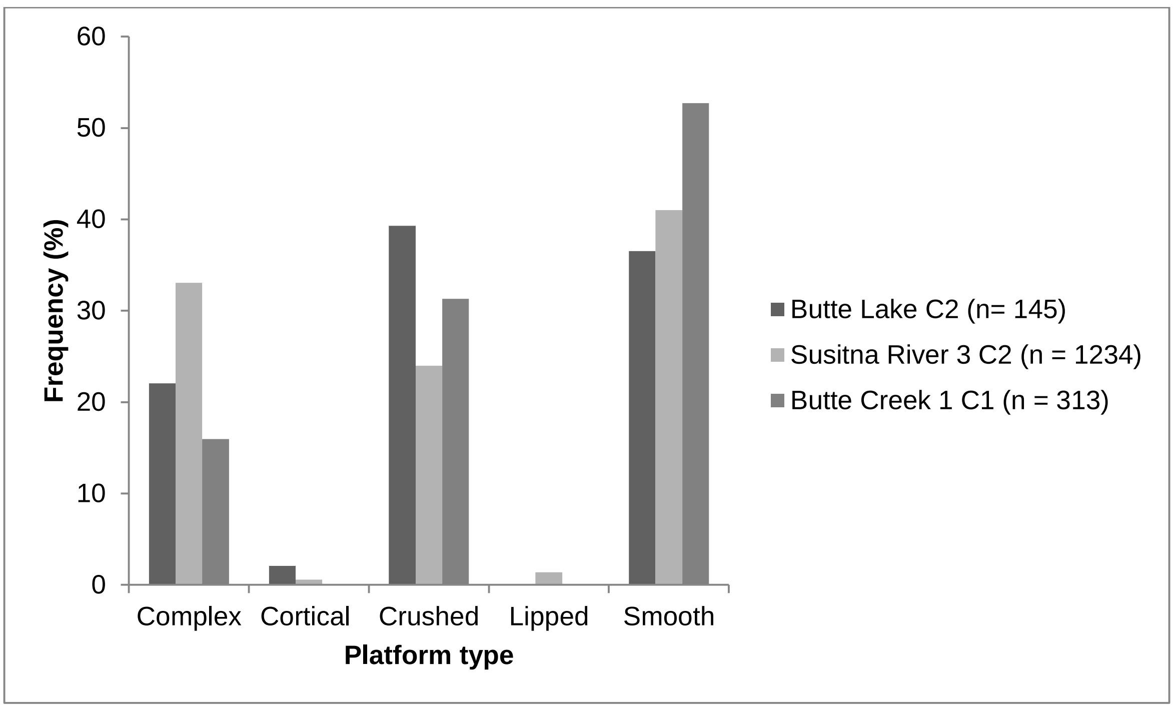

Figure 70. Platform type comparison between middle Holocene components.

The tool assemblages from Butte Lake C2, Susitna River 3 C2, and Butte Creek 1 C1 all have a high frequency of retouched flakes, but also have a diversity of other tool types (Figure 71). Susitna River 3 C2 has a low formal to informal tool ratio, while Butte Lake C2 and especially Butte Creek 1 C1 have higher ratios (Figure 72), suggesting specialized subsistence activities occurred in Butte Lake C2 and Butte Creek 1 C1. Butte Lake C2 has a lower number of complete tools when compared to the other MH sites, and has a higher tool to debitage ratio (Figure 72), suggesting that tools used in Butte Lake C2 were carried onto the site, used, then discarded. These characteristics indicate there is considerable inter-site variability in tool production, but a common thread of both formal, specialized and expedient, multipurpose tool forms at all MH sites.

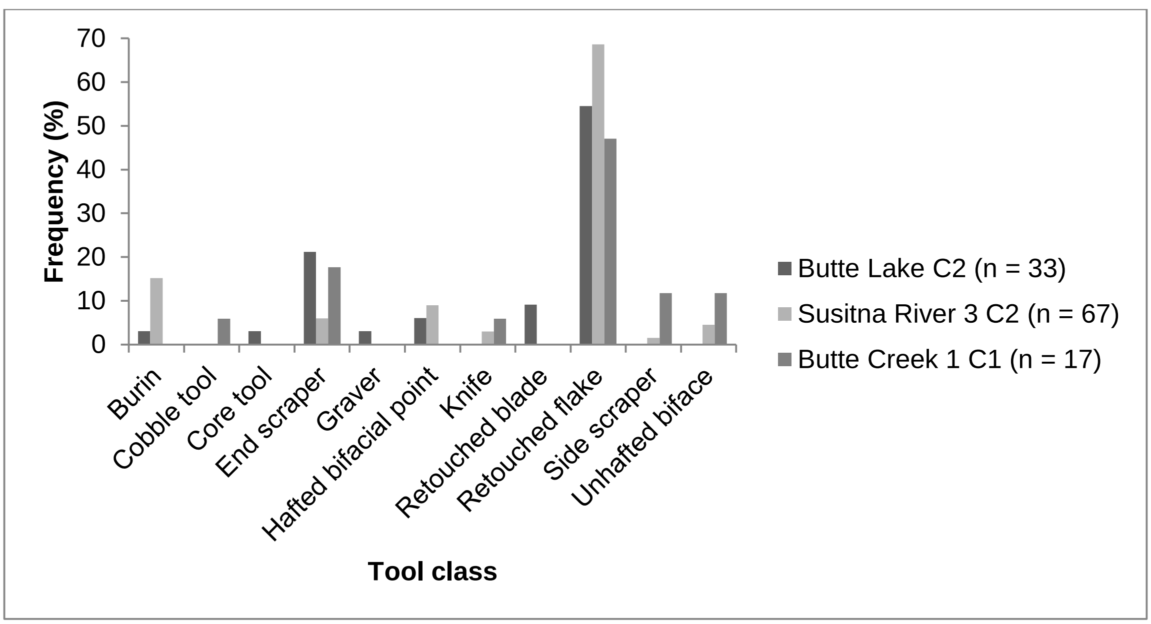

Figure 71. Tool class comparison between middle Holocene components.

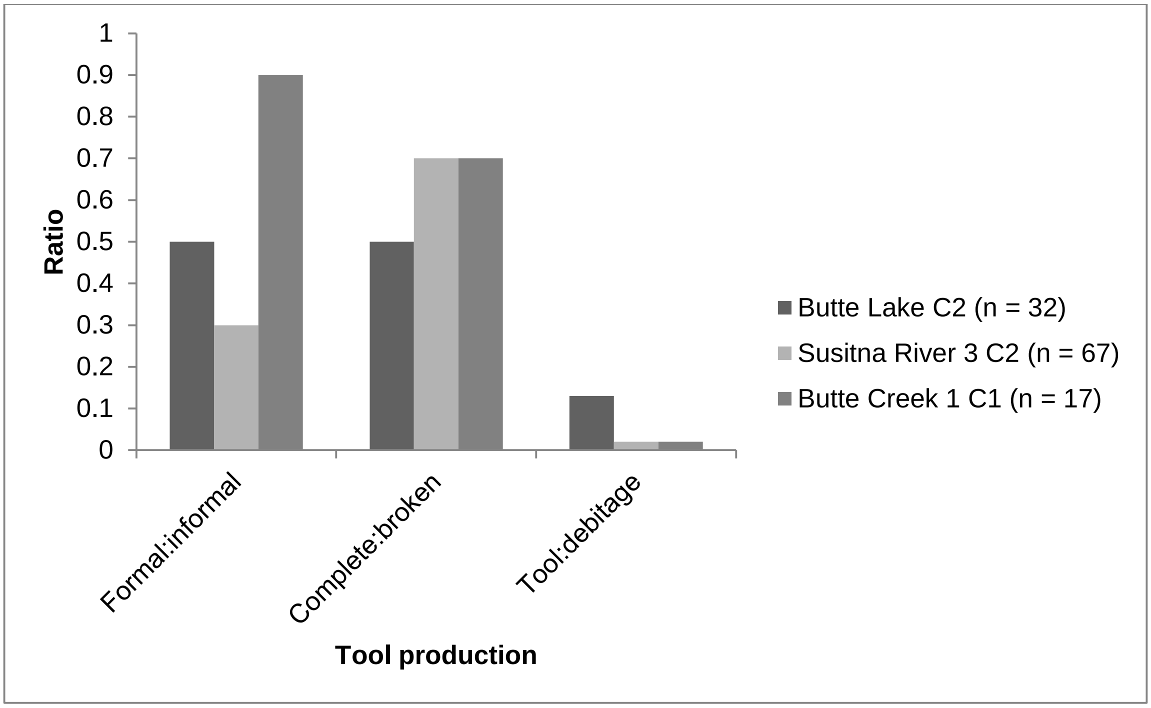

Figure 72. Tool production comparison between middle Holocene components.

Tools at all MH sites have moderate to high retouched edge unit scores, and were discarded with moderate remaining utility (Table 37). In Susitna River 3 C2 and Butte Creek 1 C1 non-local chert and rhyolite were more intensively retouched, while in Butte Lake C2 locally available basalt was more intensively retouched. The notched point assemblage from the Ratekin site provides additional information on MH formal tool production and discard. Most of the notched points are made on non-local raw material, even obsidian transported long distances, but locally available raw material was also used. Notched points are all made on informal flake blanks, suggesting informal flake core reduction, possibly with the goal of flexibility to create various specialized tool forms, including notched points. Notched points appear to have been discarded after breaking, with little effort made to rework broken points. These aspects of notched point manufacture suggest they were part of an informal, non-economizing technological strategy.

Taken together, the MH assemblage attributes presented here suggest that in Butte Creek 1 C1 and Susitna River 3 C2 non-local raw materials were economized more than local raw materials, but that in Butte Lake C2 local raw material was economized, possibly related to longer occupation span. These data suggest inter-site variability in economization of local vs. non-local raw material. Lithic raw material procurement at all MH sites focused on locally available material, with some non-local procurement, and very little long-distance transport of obsidian. There is very little cortical debitage in the MH assemblages, suggesting that initial reduction of all raw materials occurred elsewhere, and raw materials entered the site as highly reduced tools and/or cores. An important exception to this occurs in Butte Lake C2, where there is evidence of non-local raw material entering the site in unreduced nodule form.

Primary reduction was a minor component of lithic technological activities at Susitna River 3 C2 and Butte Creek 1 C1, but was a more significant component of lithic technological activity in Butte Lake C2. There are no formal cores in the MH assemblages, and very few cores in general. There are only minor amounts of technical debitage at two sites, and tool blanks are primarily informal, suggesting that core preparation was more expedient and informal. Evidence for tool scavenging is rare during the MH.

Secondary reduction occurred in high frequency at all sites in the MH. Biface production was an important secondary activity at two of three sites, but biface maintenance was rare, except at Susitna River 3 C2. Maintenance of unifacial tools occurred at all sites in the MH. Tools were more informal, but there was a moderate to high amount of formal tool production, especially in Butte Creek 1 C1. Overall, intensity of retouch was moderate to high, varied by raw material type, and tools were relatively frequently discarded complete with remaining utility. Tool to debitage ratio is relatively low, except in Butte Lake C2. There is evidence of raw material selection at all MH sites. Site density is high for MH occupations, and sites are situated on prominent overlooks, smaller landforms (e.g., esker), and lakeside settings. There is significant inter-site variability in lithic procurement and technological activities between MH components.

There are aspects of the MH assemblages that suggest low mobility, including a focus on procuring poorer-quality, locally available lithic raw material, informal core reduction and tool blank production, focus on primary reduction at some sites, rare technical debitage, informal tool production and low tool to debitage ratio at some sites, complete tool discard, overall specialized and heavy toolkit, informal notched point production and non-economizing discard, high site density, and inter-site variability. However, there are aspects of the MH lithic assemblages that suggest high mobility, including some long distance lithic raw material transport, lack of cortex on most artifacts, a focus on secondary reduction at some sites, raw material selection, formal tool production and high tool to debitage ratio at some sites.

To better understand site function in MH sites, it is important to consider site structure and the faunal record for each of these sites. Butte Creek 1 C1 and Susitna River 3 C2 both contain substantial hearth features, and fire-cracked rock was recovered from both of these components (see Chapter III). There are two adjacent hearth features in Butte Creek 1 C1, one of which contains a very dense fragmented and burned bone concentration. There is a large subangular cobble lying in between both of these features that may have been used as an anvil stone to crush the bones recovered from the hearth. There is one large hearth feature in Susitna River 3 C2, from which several finished bifacial point tips were recovered, as well as two notched projectile points.

Faunal remains from Butte Creek 1 C1 and Susitna River 3 C2 are all highly fragmented and calcined from human activity. Despite this, they are hypothesized to be Artiodactyla, probably caribou. The highly fragmented, burned state of faunal remains from both sites is thought to represent intensive processing of large game, probably focusing on caribou (Mueller 2015). Butte Lake C2 also contained several small hearth features including two that contained microblade fragments in association with a small amount of fragmented and calcined bone, and one that contained a notched projectile point (Betts 1987; Wendt 2013).

When the full suite of MH toolstone procurement and technological activities is considered, the MH assemblages have more of a signature of low mobility. The MH occupants of the study area relied mostly on locally available lithic raw materials, but also carried non-local material into the study area, and in some cases appear to have carried in unreduced nodules of non-local raw material. This could represent raw material stockpiling, especially at Butte Lake C2, possibly of raw material collected on logistical trips outside of the study area. For the most part, lithic technological activities were informal and expedient, but there are examples of more formalized, economized lithic technological activities as well. It could be that the overall poorer quality of lithic raw material in the study area resulted in economization of some non-local raw materials like chert and rhyolite.

Tool richness data indicate that of the three MH assemblages, Butte Lake C2 (BL C2) has a higher than expected highest richness value, while Butte Creek 1 C1 (BC1 C1) and Susitna River 3 C2 (SR3 C2) have lower than expected richness values (Figure 73). When compared to all assemblages from the study area, Butte Lake C2 and Butte Creek C1 have higher than expected richness values, while Susitna River 3 C2 has a lower than expected richness value (Figure 66). A high intra-site richness value suggests that Butte Lake C2 may have operated as a residential base during the MH. There are technological indications presented above that support Butte Lake C2 as a residential camp, including possible raw material stockpiling, a focus on primary reduction, and more intensive retouch of locally available raw material, possibly a signal of a longer-term occupation. A low intra-site richness measure suggests that Susitna River 3 C2 may have been a resource extraction location, and this is supported by a focus on secondary reduction and tool maintenance activities at this site. The ambiguous Butte Creek 1 C1 richness score may be related to differences in sample size when compared to all assemblages from the study area, but again a clear focus on secondary reduction and tool maintenance activities suggests this site may have been a hunting camp. The focus on local lithic raw material procurement in Susitna River 3 C2 and Butte Creek 1 C1 suggest these sites may represent short-distance logistical resource extraction camps.

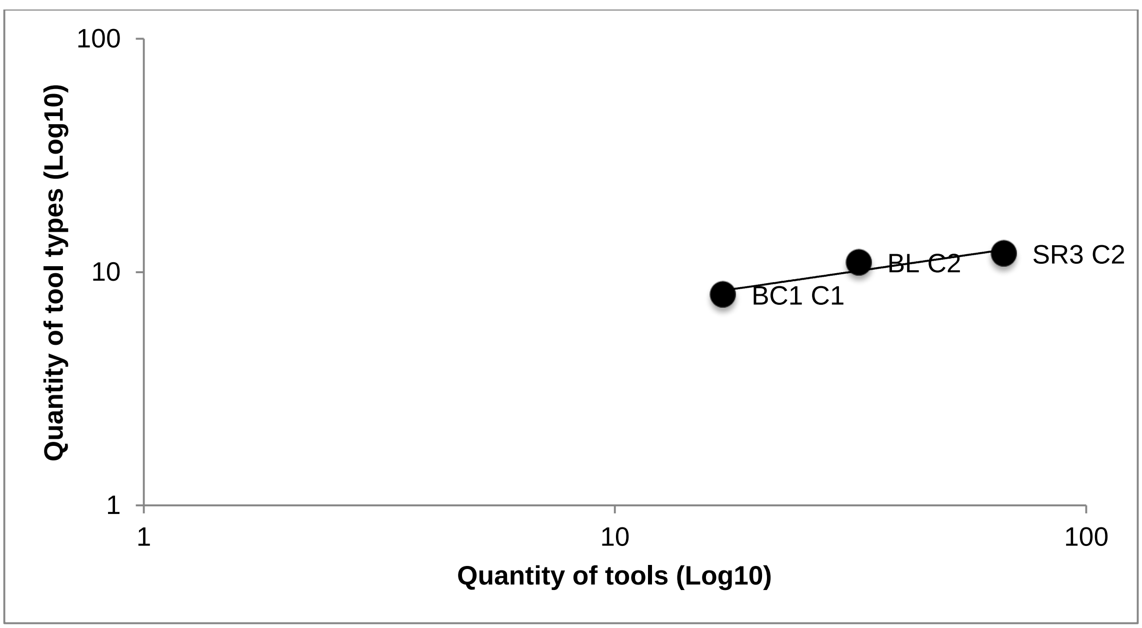

Figure 73. Tool richness for middle Holocene sites in the upper Susitna study area**.** See text for explanation of abbreviations.

Site structure and faunal data from these sites somewhat complicate these interpretations. Wendt (2013) interpreted Butte Lake C2 to be a transitory camp where hunters produced bifacial tools, possibly only occupied overnight as they were moving through the study area on a logistical foray. This interpretation was primarily based on the small size of the features at the site, but also on the high frequency of complex platforms and fewer number of small debitage pieces in the assemblage. Wendt suggests that the relatively dense accumulation of material in the C2 assemblage was related to continued re-use over time. Wendt analyzed material from both the 1987 and 2012 excavations, but focused more on the 2012 assemblage because of the more secure provenience associated with this material. Wendt's analysis also focused almost solely on analysis of debitage from the C2 assemblages.

The lithic analysis presented here contradicts Wendt's interpretation of the significant lithic technological activities occurring at the site. The lack of significant hearth features in Butte Lake C2 does seem to cast doubt on the site operating as a base camp, but the evidence for lithic provisioning of the site cannot be discounted. The interpretation of the Butte Lake C2 assemblage presented here may be stronger, because it is based on a broader set of assemblage attributes, and places the assemblage in a broader context by comparing it to other sites in the study area. However, different interpretations of the Butte Lake C2 assemblage may be the result of this study looking at a smaller sample of the lithic assemblage (only the 1987 assemblage).

Butte Creek 1 C1 and Susitna River 3 C2 have several indicators of intensive site use, including significant hearth features, fire-cracked rock, a high frequency of faunal remains, and high lithic artifact density (see Chapter III). In particular, the fact that significant hearth features were identified with minimal testing at each site suggests that with further excavation more significant features may be identified. The lithic assemblages from these sites suggest that they were resource-extraction locations in a low-mobility logistical system. However, the apparent intensity of occupation at these sites seems to contradict these sites functioning as logistical resource extraction camps.

There is ethnographic documentation for Western Ahtna hunting in the uplands in dispersed bands for most of the summer, then aggregating in the uplands during the fall caribou migration and setting up larger, more substantial camps near caribou harvesting locations. Given the site structure and faunal remains at Butte Creek 1 C1 and Susitna River 3 C2, these sites may have been logistical base camps where bands aggregated together in the fall to intensively hunt caribou. However, given the lithic record from these sites, they may have also been logistical resource extraction sites occupied more frequently throughout the summer by smaller groups operating out of logistical base camps elsewhere in the study area (e.g., Butte Lake C2). In particular, this hypothesis seems very likely for Susitna River 3 C2: the landform the site is located on is a major topographic feature that is easily accessible and has a good view shed of the study area, and may have constrained the loci of activity in study area. In fact, during our field research at this site it was visited many times by modern-day caribou hunters looking for caribou moving across Monahan Flat, providing anecdotal support for this hypothesis.

The two hearth features with dense faunal remains and a possible anvil stone at Butte Creek 1 C3 are of particular interest when compared to the ethnographic record. Reckord (1983) describes a long caribou fence in the area of Snodgrass Lake that was used to guide caribou over many miles of tundra and direct them into Snodgrass Lake, where Western Ahtna speared them from canoes using copper-tipped spears. Ahtna legend describes this disadvantage hunting technique as originating at this location. Although the location of the caribou drive line is not described by Reckord, given the topography of the area surrounding Snodgrass Lake it is reasonable to assume that the drive line was used to direct caribou down the Butte Creek drainage towards the lake. The Butte Creek site is only 1 km south of Snodgrass Lake, on a long sinuous esker landform overlooking the Butte Creek drainage. The apparent intensive resource processing in Butte Creek 1 C2 could represent an extension of this type of hunting activity in the study area from Athabaskan times back to the MH.

It is likely that the apparent palimpsest nature of the lithic assemblages from these sites contributes to the seemingly contradictory nature of the archaeological evidence. MH reoccupation is supported by the diversity of raw material types recovered from each site, as well as radiocarbon dates associated with each component that show occupations hundreds of years apart.

These data suggest that MH occupants of the upper Susitna basin moved into the study area carrying some non-local raw material, primarily rhyolite and chert but also some obsidian, and occupied the study area for a relatively long period of time, perhaps setting up a base camp nearby Butte Lake and undertaking short-distance logistical forays to Butte Creek 1 and Susitna River 3, then aggregating with other bands at logistical base camps situated nearby caribou harvesting locations at Butte Creek 1 and Susitna River 3. Stockpiling of non-local raw material at Butte Lake suggests that there may have been logistical moves from Butte Lake to locations outside of the study area, possibly representing longer-distance logistical moves, but until further research expanding our lithic raw material survey coverage of the surrounding region, it is difficult to say how long these trips were. If raw material was stockpiled in Butte Lake C2, it may have been necessary because locally available lithic raw materials were poorer quality, and higher quality chert and rhyolite were more easily worked and/or stronger and more reliable materials for creating formal tools such as projectile points.

Late Holocene Lithic Technological Organization in the Upper Susitna Basin

There are four components that can be used to characterize LH lithic technological organization in the study area (Table 37). Raw material procurement at most sites in the LH focused on locally available sources, except in Susitna Dune 4 C3, where non-local material is more common (Figure 74). At most LH sites there is evidence for long-distance transport of obsidian. There are significant differences in the proportion of local vs. non-local raw material between LH sites ($\chi^2 = 413.641$; $df = 3$; $p < 0.0001$), indicating inter-site variability in lithic raw material procurement. In Susitna Dune 1 C3, Susitna River 3 C3, and Susitna Dune 4 C3 there are higher than expected counts of non-local material, while in Alpine Creek 8 C1 there are higher than expected counts of local material. A comparison of debitage sizes between LH components shows that debitage in most sites is primarily small and very small; the exception to this is Alpine Creek 8 C1 (Figure 75). Debitage size data suggest that secondary reduction was the dominant technological activity at each of these sites, with the exception of Alpine Creek 8 C1, where more primary reduction occurred.

There are significant differences in the proportions of primary and secondary debitage between LH sites ($\chi^2 = 195.162$; $df = 3$; $p < 0.0001$), suggesting inter-site variability in lithic technological activities. In Susitna Dune 1 C3, Susitna River 3 C3, and Susitna Dune 4 C3 there are lower than expected counts of primary reduction debitage, while at Alpine Creek 8 there are higher than expected counts of primary reduction debitage.

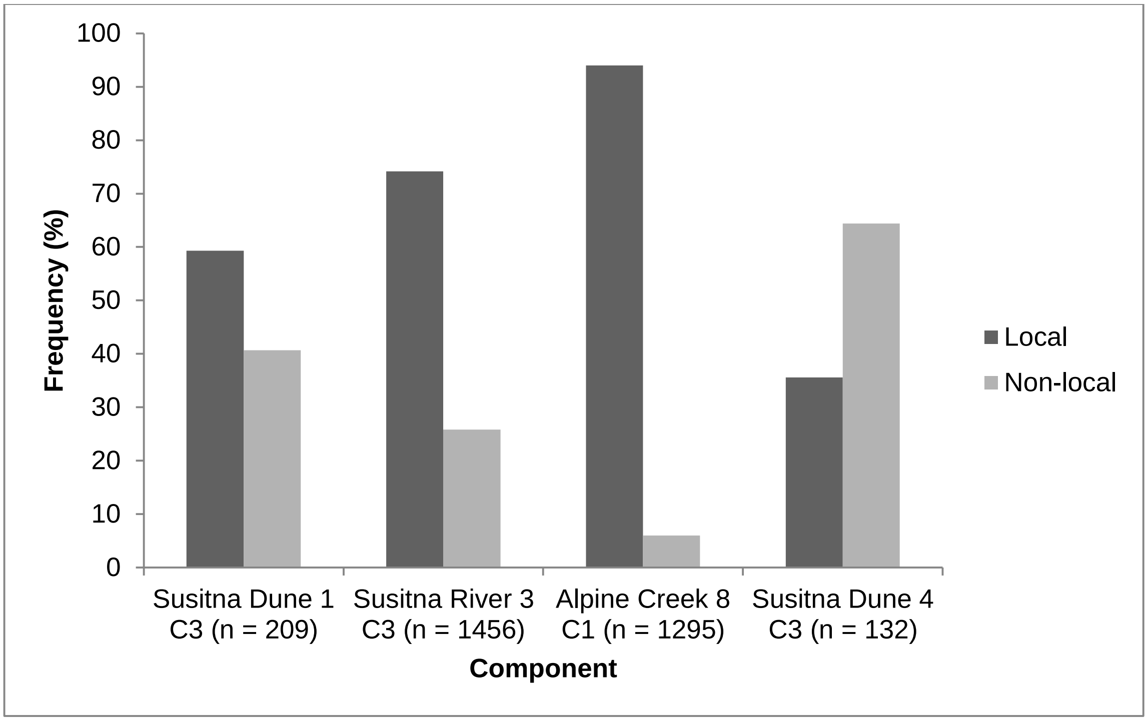

Figure 74. Local versus non-local lithic raw material procurement comparison between late Holocene assemblages.

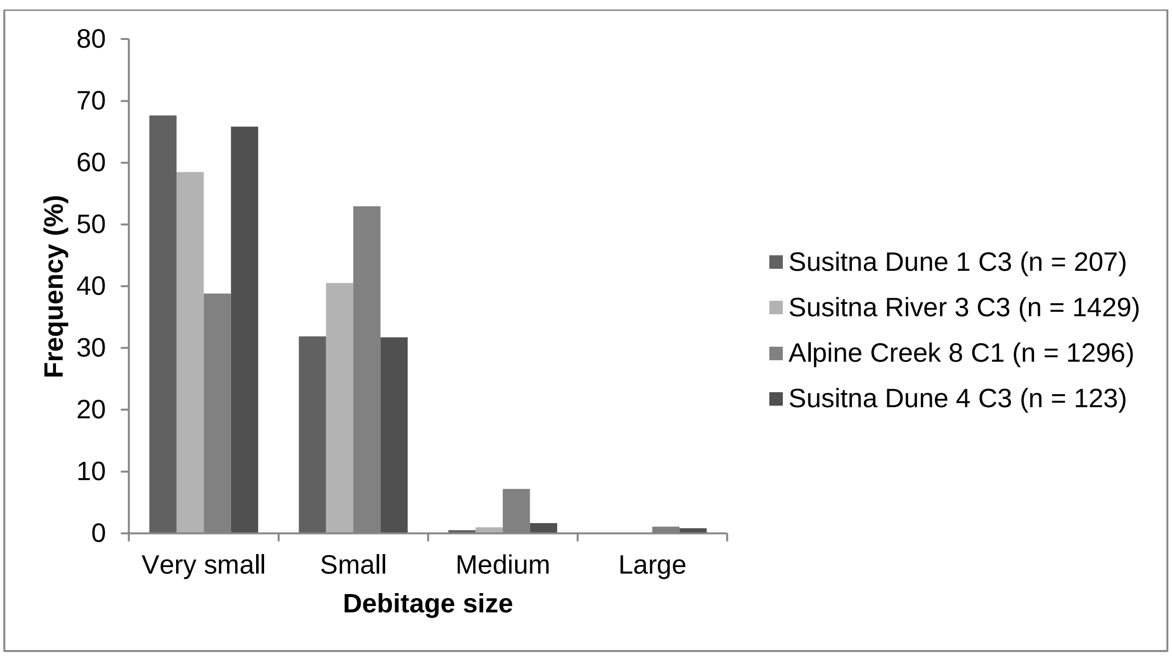

Figure 75. Debitage size comparison between late Holocene assemblages.

A focus on secondary reduction at most LH sites is further supported by comparison of debitage classes between components (Figure 76). Debitage class data for most sites indicate that retouch was the dominant activity; the exception to this is again Alpine Creek 8 C1, where there are more flake fragments than retouch chips. This suggests that many of the very small debitage pieces presented above were likely the result of flakes chattering during uncontrolled flake core reduction in Alpine Creek 8 C1, supporting a focus on informal flake core reduction. The high frequency of flake fragments in the Alpine Creek 8 C1 assemblage may be due to the brittle nature of the locally available argillite being reduced at the site. The low frequency of cortical spalls in all assemblages indicates that very little initial reduction occurred at these sites.

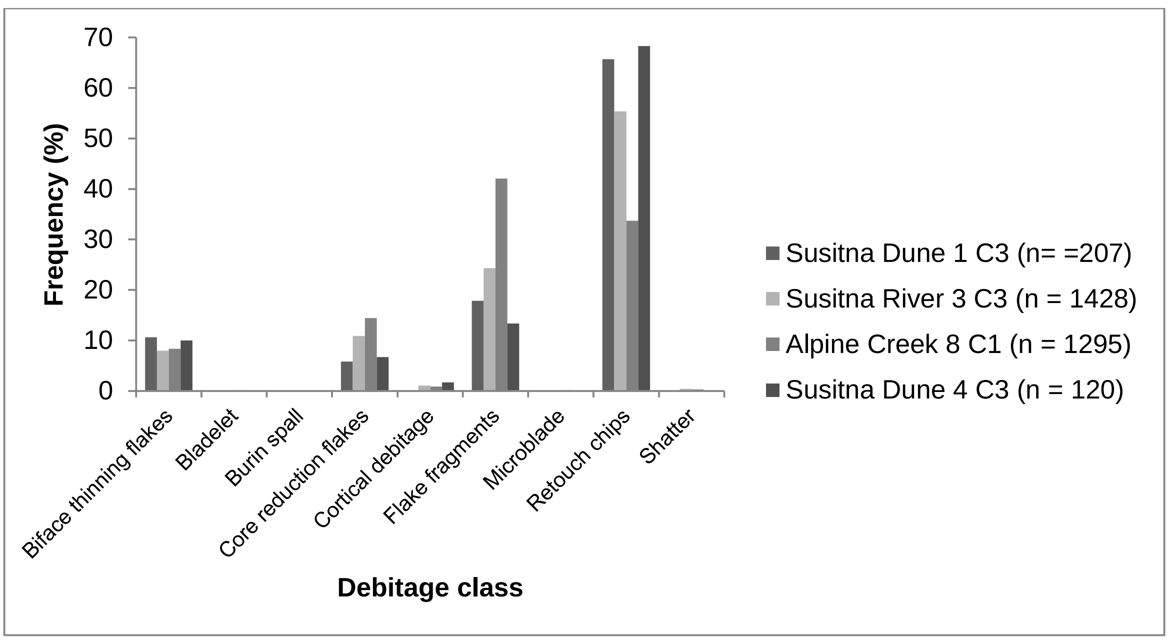

Figure 76. Debitage class comparison between late Holocene components.

A comparison of proximal debitage platform type between LH components shows considerable variability in platform type (Figure 77). Susitna Dune 4 C3 has more complex platforms and less crushed platforms than most LH sites, while Alpine Creek 8 has more smooth platforms than other sites, and Susitna River 3 C3 has more crushed platforms than other LH sites. These data suggest that more formal reduction occurred in Susitna Dune 4 C3, and more informal reduction occurred in Alpine Creek 8 C1. The high frequency of crushed platforms in Susitna River 3 C3 could represent uncontrolled reduction of relatively low-quality chalcedony reduced at this site. The low frequency of crushed platforms in Susitna Dune 4 C3 could represent more formal, controlled reduction of high-quality chert.

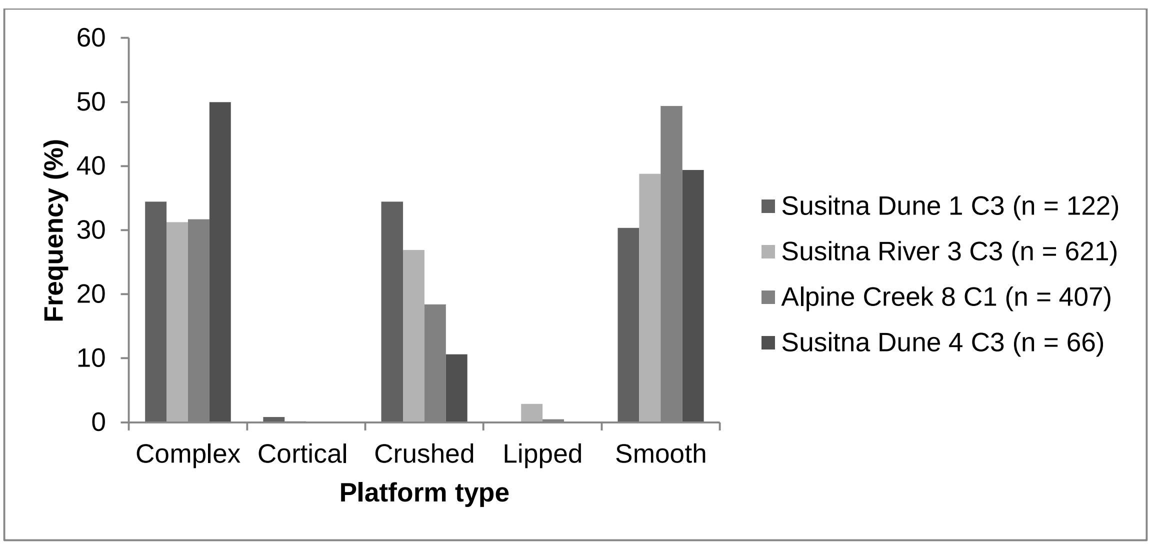

Figure 77. Platform type comparison between late Holocene components.

Tool assemblages in LH components are generally similar, in that they are dominated by informal retouched flakes, and contain hafted and unhafted bifaces. For all sites except Susitna River 3 C3, tool counts are low (Figure 78). Tools in the Susitna River 3 C3 and Alpine Creek 8 C1 assemblages are more formal, are more frequently discarded broken; these sites also have a lower tool to debitage ratio. Tools in the Susitna Dune 4 C3 assemblage are more informal, and discarded complete; this site has a higher tool to debitage ratio (Figure 79). These data suggest that subsistence activities at these sites required specific formal tools (e.g., hafted bifaces), as well as expedient multipurpose tools (e.g., retouched flakes).

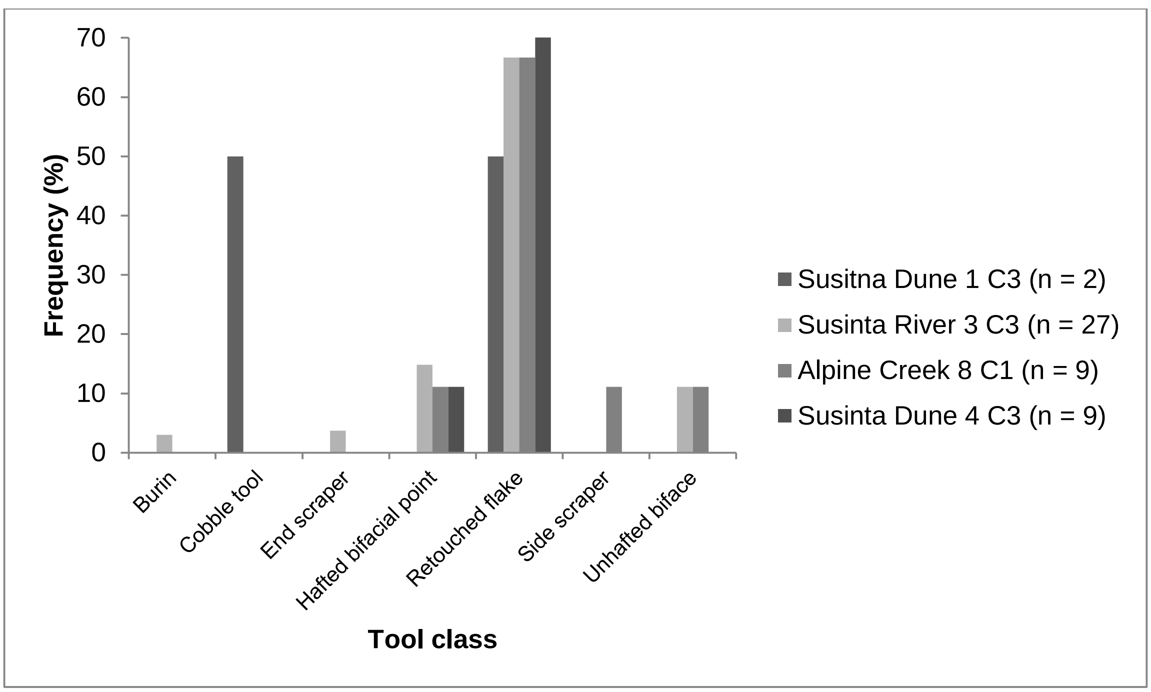

Figure 78. Tool class comparison between late Holocene components.

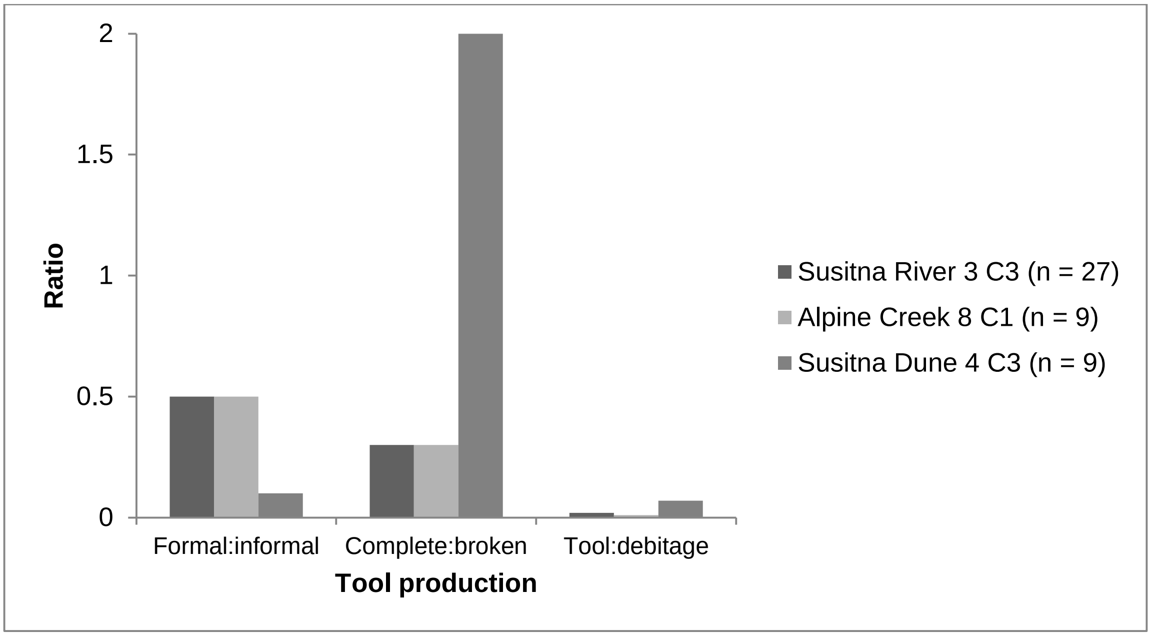

Figure 79. Tool production comparison between late Holocene components.

At Susitna River 3 C3 and Alpine Creek 8 C1, tools appear to have been made onsite, used until broken, then discarded. At Susitna Dune 4 C3, raw material appears to have entered the site as retouched flakes that were used onsite, and then discarded. Tools in the LH assemblages have moderate retouched edge scores, except for Susitna Dune 4 C3, which has a low score. Tools at all LH sites have low retouch index scores except for Susitna River 3 C3, which has a moderate score, indicating that during the LH tools were discarded with most utility remaining, suggesting economization of raw material was not important (Table 37).

Taken together, these data suggest that LH lithic raw material procurement focused on locally available raw material, except in Susitna Dune 4

C3, where the focus was on non-local material. There is very little long-distance transport of obsidian. There is very little cortical debitage in the LH assemblages, suggesting that initial reduction of all raw materials occurred elsewhere, and raw materials entered the site as highly reduced tools and/or cores. At Alpine Creek 8, primary reduction of argillite available in the valley was a significant part of technological activities, but secondary retouch was also important. There are no formal cores in the LH assemblages, and only one informal core. Technical debitage is absent except for Susitna River 3 C3, where it is a minor part of the debitage assemblage. Tool blanks are mostly informal for sites with larger tool sample sizes, except at Susitna Dune 4.

These data suggest that core preparation and reduction was expedient and informal in the LH. Evidence for tool scavenging is very rare during the LH. At Susitna Dune 1 C3, Susitna Dune 4 C3, and Susitna River 3 C3, secondary reduction dominates the debitage assemblage, focused on bifacial and unifacial tool maintenance, with biface production highlighted in Alpine Creek 8 C1 and Susitna Dune 4 C3. Maintenance of unifacial tools was decidedly informal, and non-economizing. Site density is generally lower, the exception being Alpine Creek 8 C1.

There are aspects of the LH assemblages that suggest low mobility, including a focus on poorer-quality, locally available lithic raw material (except at Susitna Dune 4), informal core reduction and tool blank production, focus on primary reduction at Alpine Creek 8, rare technical debitage, informal tool blank production, and low tool to debitage ratio (except at Susitna Dune 4). There are also characteristics of the LH assemblage that suggest high mobility, including evidence for long-distance obsidian transport at most sites, low amounts of cortical debitage, high frequency of secondary debitage at all sites but Alpine Creek 8, rare bipolar knapping/tool scavenging, moderate formal to informal tool ratio, low complete tool discard, and raw material selection for specific technological activities. In particular, the focus on non-local procurement, high tool to debitage ratio, high frequency of formal tool blank types, and low site density in Susitna Dune 4 C3 suggests this site represents activity in a high mobility settlement system.

When the full suite of LH toolstone procurement and technological activities is considered, the LH assemblages have a mixed signature of low and high mobility. Tool richness data for LH sites indicate that Alpine Creek 8 C1 (AC8 C1), Susitna Dune 1 C3 (SD1 C3), and Susitna River 3 C3 (SR3 C3) have a higher than expected tool richness score, while Susitna Dune 4 C3 (SD4 C3) has a lower than expected tool richness score (Figure 80). When compared to lithic assemblages from all sites in the study area, tool richness scores follow the same general pattern, except that Susitna River 3 C3 has a slightly lower than expected richness score (Figure 66).

These data suggest that Alpine Creek 8, Susitna Dune 1 C3, and Susitna River 3 C3 may have been residential camps, while Susitna Dune 4 C3 was a logistical resource extraction camp. Richness data also indicate considerable tool richness variability in the LH assemblages, suggesting again that these sites were functionally variable and likely occurred in a logistical system. The diversity in assemblage characteristics described above may relate to distance of logistical trip. For example, Susitna Dune 4 appears to represent a highly mobile logistical resource extraction camp, while Alpine Creek appears to represent a low mobility residential camp, possibly a logistical upland hunting/quarry camp with argillite procurement embedded in hunting activities. While Susitna Dune 1 C3 has a richness score suggesting a residential base camp, and Susitna River 3 C3 has an ambiguous richness score depending on the data set used for comparison, the full suite of technological characteristics suggests that these sites represent logistical extraction camps. It is possible that the higher than expected richness scores are related to palimpsest deposits, especially at Susitna River 3.

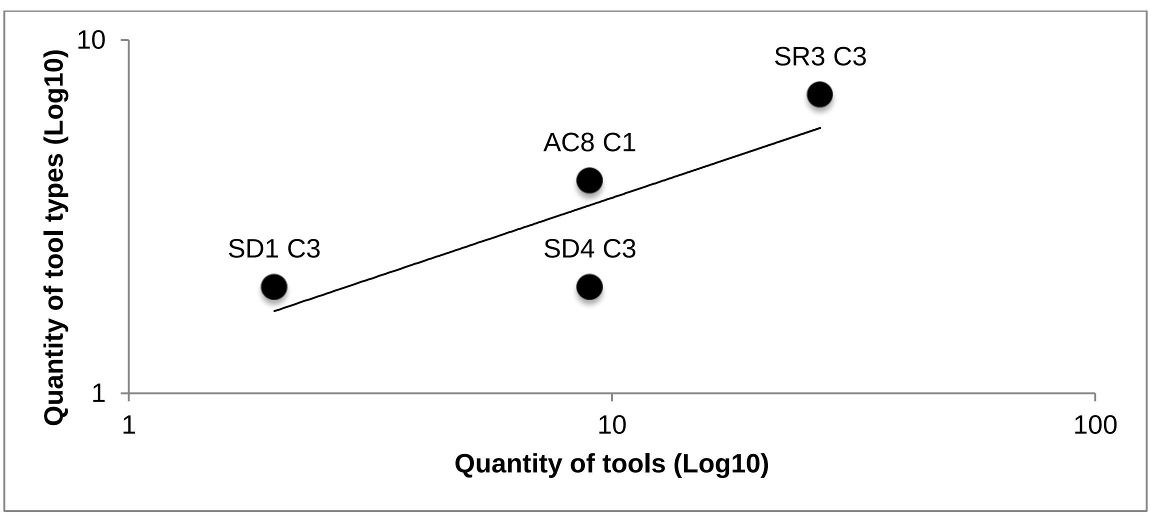

Figure 80. Tool richness for late Holocene sites in the study area. See text for abbreviations.

Site structure and faunal data from LH sites is limited, but generally support site uses inferred from the lithic assemblage data. Two of the sites contained features: Susitna Dune 1 C3 contained a small charcoal depression that may be an ephemeral hearth feature, in addition to approximately 310 small, fragmented faunal remains; Susitna River 3 C3 contained a shallow, basin-shaped charcoal feature, and approximately 160 highly fragmented faunal remains. Susitna Dune 4 C3 did not contain any features, and only three small faunal fragments were recovered. There have been no features or faunal remains identified at Alpine Creek 8 C1 to date. No fire-cracked rock was recovered from any of the LH sites. The ephemeral site structure characteristics and minimal and faunal material from Susitna Dune 1 C3, Susitna Dune 4 C3, and Susitna River 3 C3 support the use of these sites as short-term logistical resource extraction camps. The lack of hearth features at Alpine Creek 8 may not be significant; our excavations recovered almost no charcoal from anywhere at the site, possibly related to the lack of shrubs or trees to burn in the alpine setting the site is in.

Lithic Technological Organization at Undated Sites in the Upper Susitna Basin

There are two lithic assemblages from undated components presented here, Windy Creek 1 and Ratekin (Table 37). These two sites are considerably different, but are detailed here because although undated, they offer additional insight into lithic technological organization in the uppermost part of the study area. Toolstone procurement at Windy Creek 1 focused almost solely on locally available argillite lithic raw material. There is a relatively high amount of primary reduction debitage there, and core reduction appears to have focused on expedient, informal core types producing flakes for tool blanks, but bifacial cores were also reduced onsite, and biface thinning flakes were infrequently used as tool blanks.

Secondary reduction was a lesser component of technological activities at Windy Creek 1, and it focused on producing and maintaining bifacial tools, as well as some unifacial tool maintenance. The tool assemblage form the site is small, but suggests that tools were both formal and informal types, retouched with moderate intensity, and discarded broken, with high remaining utility. A relatively low tool-to-debitage ratio suggests that tools used at Windy Creek 1 were produced onsite. There is no evidence of raw material selection for particular types of reduction, but a single raw material class dominates the assemblage, so this may not be meaningful (Table 37).

When tool richness at Windy Creek 1 is compared to richness scores for the rest of the sites in the study area, the site has a higher than expected tool richness score, suggesting it could be a residential base camp (Figure 66). This is supported by the apparent focus on primary reduction at the site. It is likely that this site represents an LH upland hunting/quarry camp, similar to Alpine Creek 8. If the site is tested, the depositional environment will probably be very similar to Alpine Creek 8, and may not be able to be dated. Regardless of the time of occupation, the site is an example of a low-mobility site with a focus on biface production in an alpine setting. Windy Creek 1 was most likely a logistical base, from which hunters targeted caribou in the upper evelations of the Clearwater Mountains.

The Ratekin site is unique because it has a relatively large core and tool assemblage when compared to the rest of the sites in the study area, and is useful for evaluating core and tool production, use, and discard in an upland setting. At Ratekin, raw material procurement focused on non-local material, but also a significant amount of locally available raw material, too. The Ratekin assemblage has the highest percentage of artifacts with cortex when compared to all assemblages in the study area, an interesting characteristic considering that the assemblage consists primarily of tools. All of the cores in the assemblage are informal types, and tools were primarily made on informal tool blanks. There are more examples of bipolar knapping and tool recycling at Ratekin than at other sites, but it is still a relatively minor part of the assemblage.

The Ratekin assemblage has by far the highest ratio of formal to informal tools in the study area, and most of these tools exhibit high retouch intensity and were discarded complete, but with little utility remaining. There does not appear to be any raw material selection in tool production (Table 37). Tool richness data from the Ratekin site indicate that the assemblage has a slightly higher than expected tool richness, suggesting it may have been a residential base camp (Figure 66).

While the Ratekin site is undated, there is support for a MH and LH occupation of the site. Site structure and faunal data are limited, but there were reportedly several hearth features, some rock lined, and fragmented animal bone were described at the site (Skarland and Keim 1958). In addition, the Ratekin rock-wall blinds are significant features not found at any other sites in the study area. There are characteristics of the Ratekin lithic assemblage that support occupation by highly mobile groups, including a focus on non-local procurement, including long-distance procurement of obsidian, presence of technical debitage (albeit just one piece), high formal-to-informal tool ratio, and high reduction intensity.

Lithic assemblage characteristics supporting low mobility include use of many local raw materials, a relatively high percentage of tools bearing cortex, evidence for mostly informal core reduction, no raw material selection, rare formal tool blank production, high reduction intensity if related to length of occupation, high complete to broken tool ratio, specialized toolkit with many tool types, overall heavy toolkit, and evidence for bipolar knapping/recycling.

Taken together, there are many aspects of the Ratekin lithic assemblage that support the site operating as a base camp in a low mobility land-use system; this is supported by the reported hearth features and fire-cracked rock at the site. It is possible that the presence of more non-local raw material is related to stockpiling of raw materials collected during long-distance logistical trips from the site to locations outside of the study area. The unexpectedly high formal to informal tool ratio may be the result of sampling strategy; it is apparent from the assemblage that little attention was given to debitage during surface collection. Likewise, formal tools may have been preferentially collected over informal flake tools. Intensive tool retouch in this case appears to be related to length of stay, not mobility.

The hunting blinds on the upper bench of the site support the use of this part of the site as a hunting lookout. Again, the limited information on surface collection methods leaves little details about where most of the lithic material came from, but it reasonable to assume that there was not a base camp immediately next to the rock-wall blind ambush location, so the base camp may have been located on the lower bench of the site, or may date to an earlier time than the blinds and are unrelated. This fits expectations that a logistical camp will often be placed next to a known resource. Given these data, the Ratekin site appears to have been a logistical base camp occupied in the MH and LH in a low mobility logistical system.

What is the Nature of Upland Use Throughout the Holocene?

The lone EH assemblage at Susitna River 3 has characteristics of a highly mobile land-use system, with individuals moving into the study area provisioned with the toolstone and prepared cores they needed for specialized subsistence activities. The lithic technological signature from the EH component is different from the MH and LH components in that there is a focus on burins, as well as small tools made on flakes, bladelets, and microblades. The high-quality material that dominates this assemblage is not present in significant proportions in any other assemblage.

It is difficult to discuss broad patterns of landscape use from the lithic assemblage at one site, but these assemblage characteristics suggest that EH occupants of the study area entered on long-distance logistical forays from a logistical base camp outside of the study area. It is possible that Susitna River 3 C1 represents a long-distance logistical resource extraction camp tied to a base camp in the lowlands. Logistical forays into the uplands from lowland camps have been inferred from other sites in the Alaska Range during the Younger Dryas, and they are hypothesized to represent a response to a YD shift to increased grass and forb biome that was favorable for mobile herd animals such as bison, wapiti, and caribou (Graf and Bigelow 2011). Previous research also suggests that the earliest Holocene was a time of expanded subsistence ranges, including forays through the uplands of the central Alaska Range (Mason et al. 2001). The early Holocene Susitna River 3 C1 assemblage may represent a similar land-use strategy extending into southcentral Alaska.

The earliest radiocarbon dated sites in the upper Susitna study area are from the EH; as detailed above, previous research suggests that in the EH hunter-gatherers abandoned the foothills and uplands of the central Alaska Range as climate warmed and became more mesic, re-focusing subsistence in the Tanana lowlands (Graf and Bigelow 2011), or even abandoning large parts of interior Alaska due to a population decline in response to the spread of boreal forest and accompanying lower carrying capacity (Potter 2008a). In the upper Susitna basin, we see evidence for a highly mobile group occupying the study area during this time. This could represent an initial foray into southcentral Alaska, by people pushed out of interior Alaska by a dramatically changing ecosystem.

It is possible that the upper Susitna basin remained a grass and forb biome throughout the earliest Holocene, offering a refugium for faunal species pushed out of the greater Tanana basin by spreading spruce forests. Certainly the Cervidae faunal remains from Susitna Dune 1 C1 support this. Further paleoecological research is needed in the upper Susitna basin to determine what the sequence of vegetation change was for the LP and EH.

The earliest sites on the southern flank of the Alaska Range (those presented here from the upper Susitna study area, Jay Creek Ridge in the Talkeetna Mountains, and the Tangle Lakes sites) all date to a period of abandonment in interior Alaska, again suggesting that the impetus for colonizing the upper Susitna basin and broader southcentral Alaska may have been the dramatic ecological shift in interior Alaska. Caribou (*Rangifer tarandus*) were present throughout all of Beringia in the late Pleistocene (Hoffecker and Elias 2007). Following deglaciation of southcentral Alaska, genetic evidence indicates that caribou populated southcentral Alaska from the north, from a larger Beringian population that persisted through the glacial period (Flagstad and

Roed 2003). The Nelchina herd ranges over 51,800 km^2 of caribou habitat across southcentral Alaska, moving great distances during its seasonal rounds, through spring calving, summer and early fall range, fall rut, and winter range. The nature and location of seasonal movement can vary annually, but generally follow an east to west seasonal pattern; the most consistent characteristic of Nelchina herd movement is spring calving in the eastern Talkeetna Mountains (Hemming 1971; Pitcher 1984; Skoog 1968; Schwanke 2011; Toobey 2009).

The earliest sites in southcentral Alaska are all situated near important seasonal caribou locations; the Tangle Lakes sites are nearby historically known spring and fall caribou migration routes of the Nelchina herd (Robinson 2008), Jay Creek Ridge is located in the eastern Talkeetna Mountains nearby historically known spring calving grounds for the Nelchina herd, and Susitna River 3 C1 and Susitna Dune 1 C1 are within the historically known summer range of the Nelchina herd. If the Nelchina herd had established a seasonal migration pattern similar to that known historically, then this would have been a significant subsistence resource available at relatively certain locations certain times of the year. This may have been the impetus for colonizing populations moving south through the Alaska Range, as the boreal forest pushed from lowland valleys into the foothills on the northern flank of the Alaska Range.

The EH site data presented here, although meager, offers preliminary support for the hypothesis that hunter-gatherers operated in a highly mobile logistically oriented settlement pattern in the YD, and that this pattern extended into the earliest Holocene in the upper Susitna study area. These data casts doubt on a pre-6000 cal BP focus on residential mobility constrained to the lowlands (Potter 2008a, 2008b, 2008c), although this needs to be explored more with additional assemblages from this time period.

In the MH there is a clear shift in landscape use in the study area; there are more archaeological sites, sites are denser, there are intensive processing features, and sites have more locally available, often poorer-quality raw materials. Toolkits consist of a variety of tools including various processing tool types. Bifacial hunting weaponry was an important part of lithic technology. These attributes suggest less mobile groups staying for longer periods of time in the study area, and undertaking a variety of subsistence activities. Several MH sites appear to have operated as logistical base camps, and there are possible examples of aggregate hunting camps as described in the protohistoric and historic periods. Occupants of the study area during the MH appear to have operated in a low-mobility logistical system, one that provisioned site locations with lithic raw materials necessary for subsistence activities.

Sites in the MH generally have higher tool richness scores when compared to the EH and LH (Figure 36). Given the site structure and faunal evidence described above, these data suggest that sites investigated for this study were used more intensively during the MH than the EH and LH. We did not find any significant structural features during our field research like the ones described for winter villages in the lowland Copper River basin, suggesting that none of the sites excavated during this project were longer-term winter encampments but instead were spring/summer/fall camps with temporary structures. This supports the notion that the study area was used for dispersed summertime hunting, as well as aggregate hunting, probably for the fall caribou hunt. These data support previous research showing a shift in landscape use during the MH to a logistically-oriented mobility system, with increased seasonal use of upland subsistence resources (Potter 2008c).

Changes in raw material procurement in the MH have important implications when PXRF geochemistry data are considered. The EH occupants of the study area came prepared with quality raw material, but this did not include obsidian. Previous research in interior Alaska indicates that the earliest occupants of Alaska made use of several disparate obsidian sources across interior Alaska, and that the occurrence of obsidian in archaeological assemblages from far-off source locations is likely the result of direct procurement, possibly representing extended mobility ranges for highly mobile groups. Increased use of obsidian in the MH and LH, including increased distance between use and source location, is thought to represent the development of a larger population base and establishment of trade networks (Reuther et al. 2011). This has implications for interpreting obsidian procurement in this study; EH occupants of the site may not have had a mobility range that extended to areas with the closest known obsidian sources, suggesting a mobility range of less than 350 km. Middle Holocene sites have obsidian from three different sources, two of which are known and are hundreds of km in opposite directions from the study area, supporting the emergence of trade networks transporting obsidian to the study area.

Rhyolite becomes more common in the MH, and there is evidence for rhyolite entering several sites as unreduced or initially reduced nodules or cores, as well as in the form of finished tools. Rhyolite is often more intensively maintained than locally available raw material. Recent PXRF geochemical research suggests that increased rhyolite use is an indicator of increased intensification of uplands use in the MH. Only one rhyolite artifact from the study area has been geochemically analyzed, the piece from Ratekin described above. This piece is attributed to source group A, the location of which is unknown, but is probably located in the north-central Alaska Range. More interesting to this research is the evidence for at least one, and possibly several rhyolite sources in the Talkeetna Mountains just southwest of the study area (Coffman and Rasic 2015). Rhyolite sources in close proximity to the study area can explain the unexpectedly high frequency of cortical rhyolite debitage and tools in several MH and LH assemblages. Rhyolite may have been made into formal tools to maximize utility relative to the cost of transporting this raw material to the study area, although this does not explain the apparent transport of unreduced nodules.

In the LH there is an increasing reliance on locally available lithic raw materials in most cases, but an exception at Susitna Dune 4 of non-local materials dominating an assemblage. There are more LH sites in the study area, but the artifact assemblages are not as dense as in the MH. At Alpine Creek 8 and Windy Creek 1 we see upland lithic quarrying, supporting the importance of locally available toolstone. Toolkits consist of a variety of tools including various processing tool types. Bifacial hunting weaponry was an important part of lithic technology.

When LH tool richness is compared to EH and MH assemblages, it is clear that LH sites have the lowest tool richness scores of all sites in the study area. This could be related to length of occupation at these sites, the size of groups using these sites, or possibly due to small tool sample sizes in LH assemblages. Taken together, these data suggest that LH occupants of the study area appear to have been operating in a logistically mobile system, occupying the sites presented here as resource extraction locations, often from nearby logistical base camps, but possibly from logistical camps outside of the study area as well as documented at Susitna Dune 4 C3.

As with the MH sites, we did not find any significant structural features like those described for winter villages in the lowland Copper River basin, suggesting that the LH sites were spring/summer/fall camps. In the LH Butte Lake C3 component there is a house pit and evidence for intensive caribou processing; this was interpreted to be a caribou hunting camp that was likely occupied in the fall (Wendt 2013).

The LH sites presented here appear to be a result of dispersed small-group hunting; caribou were available in the study area year-round during the historic period, and natural cycles of range expansion and contraction aside, they were likely available year-round throughout most of prehistory. It is possible that the presence of many smaller sites in the LH is related to approach or encounter hunting by small bands of people operating out of upland summer hunting or fishing camps, like the kind described by Reckord (1983). Based on ethnohistoric evidence and archaeological evidence from Butte Lake C3, LH aggregate caribou hunting appears to have been focused around lakes, where drivelines were used to direct caribou into lakes to be dispatched from canoe.

It is possible that the apparent shift in densest site location from the MH to LH is the result of the introduction of lake-oriented disadvantage hunting techniques in the LH, while in the MH aggregate caribou hunting camps were situated on promontories. MH sites that have dense deposits and substantial features (Susitna River 3 C2, Butte Creek 1 C1) also have LH occupations, but excavations to date have not identified similar features at these sites, suggesting they were used differently in the LH. Instead, sites like Butte Lake C3 have evidence for more intensive LH/protohistoric occupations (Betts 1987; Wendt 2013).

The highly mobile logistical camp at Susitna Dune 4 C3 suggests that the study area may have been used differently at different times during the LH. Susitna Dune 4 C3 may represent a long distance foray into uplands from a lowland base camp, possibly representing a specific logistical late-winter (after stored food gone) or spring (from fish camp) trip to the study area, prior to moving into upland seasonal camps for summer/fall hunting. If trips were made in wintertime, then there may be extra stress or risk of failure unless equipped with formally prepared toolkits, and there is evidence for a focus on bifacial core reduction and biface maintenance.

Late Holocene sites in the Clearwater Mountains meet expectations for ethnographically described summer hunting camps in upland alpine settings. Alpine Creek 8 and Windy Creek 1 have characteristics of an upland hunting base camp, and given the density of lithic material at Alpine Creek 8, this could represent congregation of several bands for caribou hunting, or repeated use of the site. Today, there are deeply incised game trails up the Alpine Creek drainage and over the saddle into the Windy Creek drainage, and caribou can be seen throughout the southern Clearwater Mountains. During this study we observed groups of 5-30 caribou, consisting primarily of cows, calves, and yearlings, climbing the Alpine Creek valley while we excavated Alpine Creek 8.

How Did Upland Subsistence Activities Condition Lithic Assemblages in the Upper Susitna Basin?

The overall small size of tool assemblages from many of these sites makes it difficult to assess hunting weaponry with certainty. The Ratekin site has a substantial tool assemblage, and although undated, the site supports a focus on bifacial weaponry for upland hunting. The presence of notched points at the site indicates that this was the case in the MH, and the ethnohistoric record supports a focus on bifacial technology in the LH as well. In addition, most sites in the study area show evidence for biface production and maintenance, while very few show evidence for microblade core reduction and microblade production. One important characteristic of bifacial weaponry in the study area is that most bifaces are made on higher-quality non-local lithic raw materials like chert and rhyolite, suggesting that they were produced outside of the study area, then carried in for subsistence activities.

The limited instances of microblade technical debitage and microblade debitage indicate that some small-scale maintenance of microblade-inset tools may have occurred in the study area, but this is dwarfed by the evidence for biface production, maintenance and discard. If microblades were produced and used with high frequency in the study area, there should be a greater archaeological signature representing this activity. Sites where microblades are mass-produced typically have a high frequency of microblade debitage (Rasic and Slobodina 2008). The low frequency of microblade technology, and the apparent co-use of formally prepared microblade cores along with less rigidly controlled bladelet cores at several sites, suggest that these artifact types were not created under stressful conditions. This meets expectations for microblades produced in the spring and summer months (Goebel and Buvit 2011).

As presented above, current research suggests that bifacial projectile points were preferred for upland hunting activities. The research presented here cannot speak much to Wygal's (2009) proposal that lithic technological activities in an alpine setting during the LP and EH focused on biface production, because to date no sites in an alpine setting dating to the LP or EH have been found. The toolkit from Susitna River 3 C1 does not contain bifaces, although there is evidence for biface production and maintenance. There is also limited evidence for microblade and bladelet production at this site, but it sits in a shrub-tundra setting below 1000 masl, so it could fall into Wygal's category of a gearing-up site where microblades were produced in the fall in preparation for winter in the lowlands. Alpine Creek 8 and Windy Creek 1, both in an alpine tundra setting, have assemblages that fit Wygal's expectations for alpine hunting camps. While these two sites have not been directly dated, they appear to be late Holocene in age. This may provide evidence for an extension of Wygal's model throughout the Holocene. Potter (2008c) made a more general statement that throughout prehistory bifacial projectiles were preferred for upland hunting of caribou and sheep. The results of this study support Potter's connection of bifacial projectile technology with upland subsistence practices.

Conclusions

The lithic assemblages presented here offer a first look at lithic technological organization in the upper Susitna basin, with a focus on interpreting settlement organization, landscape use, and the effects of upland subsistence practices on lithic assemblage variability. To this end, this study offers the following seven conclusions:

1. Lithic raw material is abundant in the upper Susitna study area. The most common types of raw material found in the study area are chalcedony, argillite, and basalt; these materials are available in large package sizes, but are often coarser-grained and/or weakly metamorphosed, affecting knapping quality.
2. There is a significant shift in lithic raw material procurement and lithic technological activities from EH to LH in the upper Susitna basin study area.
3. EH assemblages have characteristics of a highly mobile land-use system, where individuals were provisioned with lithic raw materials necessary for subsistence activities, and stayed for short times in the study area on long-distance logistical forays.
4. Initial movement of hunter-gatherers into the study area may be tied to the spread of boreal forest biomes in the interior lowland and foothills

regions, coupled with the emergence of upland caribou herd populations as an important resource.

5. MH and LH assemblages have characteristics of a low mobility land-use system, where sites are provisioned with the lithic raw material necessary for subsistence activities. MH and LH groups established logistical base camps in the uplands during warmer months, forayed out to logistical resource extraction camps in the study area, and stayed in the uplands for the summer and fall seasons.
6. The location of logistical base camps appears to have changed from the MH to the LH, possibly tied to caribou hunting techniques, specifically the emergence of disadvantage hunting techniques incorporating drive lines into large lakes and hunters dispatching caribou from canoes.
7. Bifacial hunting weaponry appears to have been favored for upland subsistence activities, supporting previous research, but finished bifaces in the study area are often made on non-local material, so biface production may not have occurred in the upland study area. There is very limited evidence for microblade production and use in the uplands.

CHAPTER V

CONCLUSIONS

This study identified three important research questions concerning hunter-gatherer upland use in central Alaska: (1) the timing of upland settlement, (2) changes in upland land-use strategies over time, and (3) the influence of upland activities on central Alaskan lithic assemblage variability. This study set out to address these research issues through (1) paleovegetation analysis of a peat core from the upper Susitna River basin to provide local environmental context for human adaptation, (2) locating and investigating previously unknown archaeological sites in the upper Susitna basin, (3) archaeological testing of new and previously recorded sites in the upper Susitna basin, and (4) analysis of lithic assemblages from these sites as well as previously excavated sites in the upper Susitna basin. These data are used in the preceding chapters to assess the nature of upland landscape use throughout prehistory, provide a comprehensive characterization of upland lithic technological and settlement organization, and inform on changes in hunter-gatherer adaptations to changing paleoenvironments through time. Here I return to the research questions presented in Chapter I and assess them based on the results of the analyses presented in this dissertation.

Paleovegetation Reconstruction

There are three important research questions regarding paleovegetation in the uplands of the central Alaska Range. How did vegetation-community succession occur through the EH? When did modern vegetation communities emerge? How did tephra deposition impact local vegetation communities? This study did not conclusively answer certain research questions related to paleoecological change. The study attempted to construct a local vegetation history through the analysis of cores from peat bogs. However, there were significant methodological issues that emerged, including problems with the extraction of cores from bogs in the study area, as well as problematic chronological data. These issues made it difficult to achieve the goal of developing a high-resolution local record of paleoenvironmental change for the upper Susitna basin. Nevertheless, there are some preliminary conclusions that can be drawn from this study.

The earliest record of paleovegetation was absent from the peat cores analyzed for this study, so questions about early vegetation community succession remain. Radiocarbon-dated wood charcoal from the upper Susitna basin suggest that woody vegetation was on the landscape by approximately 12,200 cal BP, and specifically *Salix* shrubs were evident by 10,500 cal BP. Aside from these data points, we still know very little about the early paleovegetation record for the upper Susitna basin.

Modern vegetation communities appear to have been established in the upper Susitna by 6400 cal BP. There is no evidence for dramatic shifts in vegetation communities after this time, aside from possible fluctuations in spruce density, from denser stands closer to the WP633 coring location 6400 cal BP, to more scattered spruce in the middle and late Holocene. Peat deposits in the upper Susitna basin appear to have developed in the middle to late Holocene. The specific mire that the bulk of this research focused on appears to have undergone a change from fen-like setting to peat bog, possibly 3000 calendar years ago, as part of a natural vegetation succession. There are indications in the magnetic susceptibility record for at least four Holocene tephra falls in the upper Susitna basin. There are some preliminary indicators that vegetation may have been affected by Holocene tephra fall, but these need to be explored further to say with any confidence how vegetation responded to tephra deposition.

Upland Land-Use Strategies

There are two important research questions regarding upland land-use strategies over time: When did humans first occupy the upper Susitna basin, and what was the environmental context of initial occupation? What is the sequence of archaeological site occupation through the Holocene? This study found that humans first occupied the upper Susitna basin in the early Holocene, by 11,000-10,500 cal BP. This is at least 2000 years after the end of full glacial conditions, and 1000 years after the earliest hints of landscape recovery and a productive environment. As stated above, we still know very little about the environmental context of this initial occupation.

Following the initial occupation of the study area, there is evidence for human use of the study area from the early through late Holocene. Initial early Holocene use appears to have been ephemeral, but intensified in the middle and late Holocene. Middle Holocene sites are characterized by denser artifact deposits and cultural features, representing intensification of subsistence activities during this time. Late Holocene sites represent continued use of the study area, but with less dense sites, possibly representing a shift in subsistence activities during this time. There is evidence for a hiatus in human occupation of the upper Susitna region during the MH, but it is unclear whether this was directly related to deposition of the Watana tephra, climate instability during the Neoglacial Period, or simply just the result of sampling due to the limited initial testing and radiocarbon dating that occurred at the archaeological sites presented here.

Central Alaskan Lithic Assemblage Variability

There are three important questions regarding central Alaskan lithic assemblage variability: How was lithic technology organized within the uplands, and how was it affected by environmental change? Were upland users full-time residents, or seasonal migrants from lowlands? Which projectile point technologies were typically used in upland subsistence activities? This study found a significant shift in lithic raw material procurement and lithic technological activities from early Holocene to late Holocene in the upper Susitna basin study area. Early Holocene assemblages have characteristics of a highly mobile land-use system, where individuals were provisioned with lithic raw materials necessary for subsistence activities, and stayed for short times in the study area on long-distance logistical forays. Initial movement of hunter-gatherers into the study area may have been tied to the spread of boreal forest biomes in the interior lowland and foothills regions, coupled with the emergence of upland caribou herd populations as an important resource.

Middle and late Holocene assemblages have characteristics of a low mobility land-use system, where sites were provisioned with the lithic raw material necessary for subsistence activities. Middle and late Holocene groups established logistical base camps in the uplands during warmer months, forayed out to logistical resource extraction camps in the study area, and stayed in the uplands for the summer and fall seasons. The location of logistical base camps appears to have changed from the middle to late Holocene, possibly tied to caribou hunting techniques. Specifically, disadvantage hunting techniques emerged, incorporating drive lines into large lakes and hunters dispatching caribou from canoes.

Finally, bifacial hunting weaponry appears to have been favored for upland subsistence activities, supporting previous research, but finished bifaces in the study area were often made on non-local material, so biface production may not have always occurred in the upper Susitna basin. There is very limited evidence for microblade production and use in the Susitna uplands. Faunal assemblages form the upper Susitna were typically fragmented, and it was difficult to glean much subsistence information from the assemblages. However, the limited faunal data from this study indicate that caribou were an important subsistence resource in the upper Susitna basin, at least in the middle Holocene, and there is evidence that caribou were hunted in large numbers during this time.

The data presented here support intensification of upland use starting around 6000 cal BP as predicted in the *landscape-use model*, but also support long-distant logistical forays into the uplands starting in the early Holocene in the upper Susitna basin, supporting previous research suggesting that during the early Holocene mobile hunter-gatherers spread into the uplands procuring upland subsistence resources. These data also support a connection between bifacial hunting weaponry and upland hunting as predicted in the *seasonal landscape use model*, and while there is limited subsistence information available from the sites presented here, the presence of caribou remains suggests a link specifically between bifacial hunting weaponry and upland caribou hunting.

This study looked at long-term trends in lithic technological organization and landscape use and found evidence for significant changes in landscape use in response to changing ecosystems throughout the Holocene. Understanding human response to climate change in a subarctic setting will help understand how small-scale, subsistence-based societies in northern environments adapt to modern climate change. This study also provides an important case study about long-term environmental change and it's effect on human technology.

This study also identified preliminary but interesting patterns in social organization in the uplands of the central Alaska Range, particularly evidence for extensive obsidian exchange networks moving lithic raw material hundreds of kilometers across the landscape. This study also revealed evidence for seasonal aggregate band hunting focused on annual caribou migration. These characteristics of hunter-gatherer social organization need to be explored further, but offer an exciting opportunity to explore aspects of trade, territoriality, cooperation, and social structure in the uplands of the central Alaska Range.

REFERENCES

Addison, Jason A., James E. Beget, Thomas A. Ager, and Bruce P. Finney
2010 Marine Tephrochronology of the Mt. Edgecumbe Volcanic Field, Southeast Alaska, USA. *Quaternary Research* 73(2):277-292.

Ager, Thomas A. and John D. Sims
1981 Holocene Pollen and Sediment Record from the Tangle Lakes Area, Central Alaska. *Palynology* 5:85-98.

Anderson, Patricia M., and Linda B. Brubaker
1994 Vegetation History of Northcentral Alaska: A Mapped Summary of Late-Quaternary Pollen Data. *Quaternary Science Reviews* 13(1):71-92.

Anderson, P. M., M. E. Edwards, and L. B. Brubaker
2004 Results and Paleoclimate Implications of 35 Years of Paleoecological Research in Alaska. In *The Quaternary Period in the United States*, edited by A.R. Gillespie and S.C. Porter, pp. 427-440. Elsivier, Amsterdam.

Anderson. P. M., A. V. Lozhkin, W. R. Eisner, M. V. Kozhevnikova, D. M. Hopkins, L. B. Brubaker, and P. A. Colinvaux
1994 Two Late Quaternary Pollen Records from South Central Alaska. *Géographie Physique et Quaternaire* 48(2):131-143.

Andrefsky, William, Jr.
1994 Raw-material Availability and the Organization of Technology. *American Antiquity* 59(1):21-34.

2001 Emerging Directions in Debitage Analysis. In *Lithic Debitage: Context, Form, Meaning*, edited by William Andrefsky Jr., pp 2-14. University of Utah Press, Salt Lake City.

2005 *Lithics: Macroscopic Approaches to Analysis*. Second Edition. Cambridge University Press, Cambridge.

Armstrong, John T.
1995 Citzaf-a Package of Correction Programs for the Quantitative Electron Microbeam X-Ray-Analysis of Thick Polished Materials, thin-films, and particles. *Microbeam Analysis* 4(3):177-200.

Bamforth, Douglas B.
1990 Settlement, Raw Material, and Lithic Procurement in the Central Mojave Desert. *Journal of Anthropological Archaeology* 9:70-104.

Barclay, David J., Gregory C. Wiles, and Parker E. Calkin
2009 Holocene Glacier Fluctuations in Alaska. *Quaternary Science Reviews* 28(21):2034-2048.

Barton, C. Michael and Julien Riel-Salvatore
2014 The Formation of Lithic Assemblages. *Journal of Archaeological Science* 46:334-352.

Begét, James E., Richard D. Reger, DeAnne Pinney, Tom Gillispie, and Katy Campbell
1991 Correlation of the Holocene Jarvis Creek, Tangle Lakes, Cantwell, and Hayes Tephras in South-Central and Central Alaska. *Quaternary Research* 35:174-189.

Betts, Robert C.
1987 *Archaeological Investigations at Butte Lake, Alaska: A Report to the University of Alaska Museum Geist Fund.* Report on file at the Center for the Study of the First Americans, Texas A&M University.

Bever, Michael R.
2006 Too Little Too Late? The Radiocarbon Chronology of Alaska and the Peopling of the New World. *American Antiquity* (71): 595-620.

Bigelow, Nancy H.
1991 Analysis of Late Quaternary Soils and Sediments in the Nenana Valley, Central Alaska. Unpublished M.A. thesis, Department of Anthropology, University of Alaska Fairbanks, Fairbanks.

1997 Late Quaternary Vegetation and Lake Level Changes in Central Alaska. Unpublished Ph.D. dissertation, Department of Anthropology, University of Alaska, Fairbanks.

Bigelow, Nancy, Jim Begét, and Roger Powers
1990 Latest Pleistocene Increase in Wind Intensity Recorded in Eolian Sediments from Central Alaska. *Quaternary Research* 34(2):160-168.

Bigelow, N. H., and M. E. Edwards
2001 A 14,000 yr Paleoenvironmental Record from Windmill Lake, Central Alaska: Lateglacial and Holocene Vegetation in the Alaska Range. *Quaternary Science Reviews* 20:203-215.

Bigelow, N. H., and W. R. Powers
2001 Climate, Vegetation, and Archaeology 14,000-9000 cal yr BP in Central Alaska. *Arctic Anthropology* 38(2):171-195.

Binford, Lewis R.
1977 Forty-seven Trips: A Case Study in the Character of Archaeological Formation Processes. In *Stone Tools as Cultural Markers*, edited by R. V. S. Wright, pp. 24-36. Australian Institute of Aboriginal Studies, Canberra.

1978 Dimensional Analysis of Behavior and Site Structure: Learning from an Eskimo Hunting Stand. *American Antiquity* 43(3):330-361.

1980 Willow Smoke and Dogs' Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation. *American Antiquity* 45(1):4-20.

Birkeland, Peter W.
1999 *Soils and Geomorphology.* 3rd ed. Oxford University Press, New York.

Birks, Hilary H., and H. J. B. Birks
2000 Future Uses of Pollen Analysis Must Include Plant Macrofossils. *Journal of Biogeography* 27(1):31-35.

Birks, Hilary H.
2001 Plant Macrofossils. In *Tracking Environmental Change Using Lake Sediments, Volume 3: Terrestrial, Algal, and Siliceous Indicators,* edited by John P. Smol, H. J. B. Birks and William M. Last, pp. 49-74. Kluwer Academic Publishers, Dordrecht.

2007 Plant Macrofossil Introduction. In *Encyclopedia of Quaternary Science* 1st edition, edited by Scott A. Elias and Cary J. Mock, pp. 2266-2288. Elsevier, Amsterdam.

Blackford, Jeffrey J., Kevin J. Edwards, Andrew J. Dugmore, Gordon T. Cook, and Paul C. Buckland
1992 Icelandic Volcanic Ash and the Mid-Holocene Scots Pine (*Pinus sylvestris*) Pollen Decline in Northern Scotland. *The Holocene* 2(3):260-265.

Blackford, J. J., R. J. Payne, M. P. Heggen, A. de la Riva Caballero, J. van der Plicht
2014 Age and Impacts of the Caldera-Forming Aniakchak II Eruption in Western Alaska. *Quaternary Research* 82:85-95.

Blong, John C.
2011 An Early Holocene Site in the Upper Susitna Basin, Central Alaska. *Current Research in the Pleistocene* 28:25-26.

Bojnanský, Vít, and Agáta Fargašová
2007 *Atlas of Seeds and Fruits of Central and East-European Flora: The Carpathian Mountains Region.* Springer, Dordrecht.

Borchardt, G. A., P. J. Aruscavage, and H. T. Millard Jr.
1972 Correlation of the Bishop Ash, a Pleistocene Marker Bed, Using Instrumental Neutron Activation Analysis. *Journal of Sedimentary Research* 42(2):301-306.

Bowers, Peter M.
1979 The Cantwell Ash Bed, a Holocene Tephra in the Central Alaska Range. *Short Notes on Alaska Geology* 61:19-24.

1980 The Carlo Creek Site: Geology and Archaeology of an Early Holocene Site in the Central Alaska Range. Anthropology and Historic Preservation Cooperative Park Studies Unit. University of Alaska, Fairbanks.

Bowers, P. M., and J. D. Reuther
2008 AMS Re-dating of the Carlo Creek Site, Nenana Valley, Central Alaska. *Current Research in the Pleistocene* 25:58-61.

Briner, Jason P., and Darrell S. Kaufman
2008 Late Pleistocene Mountain Glaciation in Alaska: Key Chronologies. *Journal of Quaternary Science* 23(6-7):659-670.

Bryant Jr, Vaughn M., and Stephen A. Hall
1993 Archaeological Palynology in the United States: A Critique. *American Antiquity 58(2)*:277-286.

Calkin, Parker E.
1988 Holocene Glaciation of Alaska (and Adjoining Yukon Territory, Canada). *Quaternary Science Reviews* 7(2):159-184.

Chambers, Frank M., Bas van Geel, and M. Van Der Linden
2011 Considerations for the Preparation of Peat Aamples for Palynology, and for the Counting of Pollen and Non-pollen Palynomorphs. *Mires and Peat* 7(11):1-14.

Charman, Daniel J., Steven West, Ann Kelly, and John Grattan
1995 Environmental Change and Tephra Deposition: The Strath of Kildonan, Northern Scotland. *Journal of Archaeological Science* 22(6):799-809.

Child, J. K., J. E. Begét, and A. Werner
1998 Three Holocene Tephras Identified in Lacustrine Sediment Cores from the Wonder Lake Area, Denali National Park and Preserve, Alaska, USA. *Arctic and Alpine Research* 30(1):89-95.

Coffman, Samuel C.
2011 Archaeology at Teklanika West (HEA-001): An Upland Archaeological Site, Central Alaska. Unpublished M.A. Thesis, University of Alaska, Fairbanks.

Coffman, Sam and Ben A. Potter
2011 Recent Excavations at Teklanika West: A Late Pleistocene Multicomponent Site in Denali National Park and Preserve, Central Alaska. *Current Research in the Pleistocene* 29:29-31.

Coffman, Sam and Jeffery T. Rasic
2015 Rhyolite Characterization and Distribution in Central Alaska. *Journal of Archaeological Science* 57:142-157

Davis, Margaret B.
1966 Determination of Absolute Pollen Frequency. *Ecology* 47(2):310-311.

De Laguna, Frederica, and Catharine McClellan
1981 Ahtna. In: *Handbook of North American Indians Vol. 6*, edited by June Helm, pp. 641-663. Smithsonian Institution, Washington.

De Vleeschouwer, François, Brigitte V. V. Lanoé, and Nathalie Fagel
2008 Long Term Mobilisation of Chemical Elements in Tephra-Rich Peat (NE Iceland). *Applied Geochemistry* 23(12):3819-3839.

Dilley, Thomas Edward
1988 Holocene Tephra Stratigraphy and Pedogenesis in the Middle Susitna River Valley, Alaska. Unpublished MA thesis, University of Alaska, Fairbanks.

Dixon, E. J., and George S. Smith
1990 A Regional Application of Tephrochronology in Alaska. In *Archaeological Geology of North America,* Vol. Centennial Special Volume 4, edited by Norman P. Lasca and Jack Donahue, pp. 383-398. Geological Society of America.

Dixon, E. J., Jr.
1985 Cultural Chronology of Central Interior Alaska. *Arctic Anthropology* 22(1):47-66.

1993 *Quest for the Origins of the First Americans.* University of New Mexico Press, Albuquerque.

Dixon, E. J., G. S. Smith, W. Andrefsky, Jr., B. M. Saleeby, and C. J. Utermohle
1985 *Susitna Hydroelectric Project: Cultural Resources Investigations 1979-1985.* University of Alaska Museum. Submitted to Alaska Power Authority, Federal Energy Regulatory Commission Project No. 7114. Six vols. On file at University of Alaska Museum of the North, Fairbanks, Alaska.

Dixon, E. J., and G. S. Smith
1990 A Regional Application of Tephrochronology in Alaska. In *Archaeological Geology of North America*, edited by N.P Lasca and J. Donahue, pp. 383-398. Geological Society of America, Centennial Special Volume 4.

Dixon, E. James, William F. Manley, and Craig M. Lee
2005 The Emerging Archaeology of Glaciers and Ice Patches: Examples from Alaska's Wrangell-St. Elias National Park and Preserve. *American Antiquity* 70(1):129-143.

Dortch, Jason M., Lewis A. Owen, Marc W. Caffee, Dewen Li, and Thomas V. Lowell
2010 Beryllium-10 Surface Exposure Dating of Glacial Successions in the Central Alaska Range. *Journal of Quaternary Science* 25(8):1259-1269.

Edwards, M. E., P. M. Anderson, L. B. Brubaker, T. A. Ager, A. A. Andreev, N. H. Bigelow, L. C. Cwynar, W. R. Eisner, S. P. Harrison, F. S. Hu, D. Jolly, A. V. Lozhkin, G. M. MacDonald, C. J. Mock, J. C. Ritchie, A. V. Sher, R. W. Spear, J. W. Williams, and G. Yu
2000 Pollen-Based Biomes for Beringia 18,000, 6000 and 0 ^{14}C yr BP. *Journal of Biogeography* 27(3):521-554.

Eisner, Wendy R.
1991 Palynological analysis of a peat core from Imnavait Creek, the North Slope, Alaska. *Arctic* 44(4):279-282.

1997 Arctic Paleoecology and Soil Processes: Developing New Perspectives for Understanding Global Change. In *Soil Processes and the Carbon Cycle* edited by R. Lal, J.M. Kimble, R. F. Follett and B. A. Stewart, pp.127-141. CRC Press, Boca Raton.

Eisner, Wendy R., James G. Bockheim, Kenneth M. Hinkel, Thomas A. Brown, Frederick E. Nelson, Kim M. Peterson, and Benjamin M. Jones
2005 Paleoenvironmental Analyses of an Organic Deposit from an Erosional Landscape Remnant, Arctic Coastal Plain of Alaska. *Palaeogeography, Palaeoclimatology, Palaeoecology* 217(3):187-204.

Eisner, W. R., K. M. Hinkel, F. E. Nelson, and J. G. Bockheim
2003 Late-Quaternary Paleoenvironmental Record from a Palsa-Scale Frost Mound in Northern Alaska. In *Proceedings of the 8th International Conference on Permafrost*, edited M. Phillips, S. M. Springman, L. U. Arenson, pp. 229-234. Taylor and Francis, London.

Elston, Robert G., and P. Jeffrey Brantingham
2002 Microlithic Technology in Northern Asia: A Risk-Minimizing Strategy of the Late Paleolithic and Early Holocene. In *Thinking Small: Global Perspectives on Microlithization*, edited by R. G. Elston and S. L. Kuhn, pp. 103-116. Archeological Papers of the American Anthropological Association Number 12, Arlington.

Esdale, Julie A.
2008 A Current Synthesis of the Northern Archaic. *Arctic Anthropology* 45(2):3-38.

Faegri, K. & J. Iversen
1989 *Textbook of Pollen Analysis.* 4th ed. Wiley, Chichester.

Ferrians, Oscar J. J.
1963 Glaciolacustrine Diamicton Deposits in the Copper River Basin, Alaska. In Short Papers in Geology and Hydrology Articles 60-121: Geological Survey Research 1963 pp. C121-C125. Geological Survey Professional Paper 475-C, Washington, D.C.

Ferrians, Oscar J.
1989 Glacial Lake Ahtna, Copper River Basin, Alaska. In *Late Cenozoic History of the Interior Basins of Alaska and the Yukon*, edited by L. D. Carter, Thomas D. Hamilton and John P. Galloway, pp. 85-88. U. S. Geological Survey, Washington D.C.

Finkelstein, Sarah A.
2003 Identifying Pollen Grains of Typha latifolia, Typha angustifolia, and Typha ×glauca. *Canadian Journal of Botany* 81(9):985-990.

Fitzpatrick, E. A.
1997 Arctic Soils and Permafrost. In *Ecology of Arctic Environments: 13th Special Symposium of the British Ecological Society.* Vol. 13, edited by S. J. Woodin and M. Marquiss, pp. 1-40. Blackwell Science, Malden, Massachusetts.

Flenniken, J. Jeffrey
1987 The Paleolithic Dyuktai Pressure Blade Technique of Siberia. *Arctic Anthropology* 24(2):117-132.

Froggatt, P. C.
1992 Standardization of the Chemical Analysis of Tephra Deposits. Report of the ICCT Working Group. *Quaternary International* 13:93-96.

Gallant, Alisa L., Emily F. Binnian, James M. Omernik, and Mark B. Shasby
1995 *Ecoregions of Alaska.* U.S. Geological Survey Professional Paper 1567, United States Government Printing Office, Washington.

Gatti, Emma, Saidin Mokhtar, Khairunnisa Talib, NurAsikin Rashidi, Philip Gibbard, and Clive Oppenheimer
2013 Depositional Processes of Reworked Tephra from the Late Pleistocene Youngest Toba Tuff Deposits in the Lenggong Valley, Malaysia. *Quaternary Research* 79(2):228-241.

Gehrels, Maria J., Rewi M. Newnham, David J. Lowe, Shirley Wynne, Zoë J. Hazell, and Chris Caseldine
2008 Towards Rapid Assay of Cryptotephra in Peat Cores: Review and Evaluation of Various Methods. *Quaternary International* 178(1):68-84.

Glascock, M. D., G. E. Braswell, and R. H. Cobean.
1998. A Systematic Approach to Obsidian Source Characterization. In: *Archaeological Obsidian Studies: Method and Theory*, edited by Steven Shackley, M., pp 15-65. Plenum Press, New York.

Glaser, P. H.
1981 Transport and Deposition of Leaves and Seeds on Tundra -A Late-Glacial Analog? *Arctic and Alpine Research* (13):173-182.

Goebel, Ted, and Ian Buvit
2011 Introducing the Archaeological Record of Beringia. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia*, edited by Ted Goebel and Ian Buvit, pp. 1-32. Texas A&M University Press, College Station, Texas.

Goebel, T., W. R. Powers, and N. H. Bigelow
1991 The Nenana Complex of Alaska and Clovis Origins. In *Clovis Origins and Adaptations*, edited by Robson Bonnichsen and Karen L. Turnmire, pp. 49-80. Center for the Study of the First Americans, Oregon State University, Corvallis.

Goebel, Ted, Julie Esdale, Melissa Mueller and Caroline Ketron
2014 New Prehistoric Archaeological Research in the Blair Lakes Area, Tanana Valley, Alaska. Presentation given at the 41st annual meeting of the Alaska Anthropological Association, Fairbanks, Alaska.

Graf, Kelly E.
2008 *Uncharted Territory: Late Pleistocene Hunter-Gatherer Dispersals in the Siberian Mammoth-Steppe*. Unpublished PhD. Dissertation, Department of Anthropology, University of Nevada, Reno.

2010 Hunter–Gatherer Dispersals in the Mammoth-Steppe: Technological Provisioning and Land-Use in the Enisei River Valley, South-Central Siberia. *Journal of Archaeological Science* 37:210-223.

Graf, Kelly E., and Nancy H. Bigelow
2011 Human Response to Climate During the Younger Dryas Chronozone in Central Alaska. *Quaternary International* 242(2):434-451.

Graf, Kelly, and Ted Goebel,
2009 Upper Paleolithic Toolstone Procurement and Selection at the Sites of Dry Creek, Alaska and Ushki-5, Russia. In *Lithic Materials and Paleolithic Societies*, edited by B. Blades and B. Adams, pp. 54-77. Blackwell Publishers, London.

Graf, Kelly E., Lyndsay M. DiPietro, Kathryn E. Krasinski, Angela K. Gore, Heather L. Smith, Brendan J. Culleton, Douglas J. Kennett, and David Rhode
2015 Dry Creek Revisited: New Excavations, Radiocarbon Dates, and Site Formation Inform on the Peopling of Eastern Beringia. *American Antiquity* 80(4): 671-694.

Grayson, Donald K., and Stephen C. Cole.
1998 Stone Tool Assemblage Richness During the Middle and Early Upper Palaeolithic in France. *Journal of Archaeological Science* 25:927-938.

Guillemette, Renald N.
2008 Electron Microprobe Techniques. In *Methods of Soil Analysis Part 5-Mineralogical Methods* edited by by L.R. Drees and A.L. Ulery, pp. 335-365. Soil Science Society of America, Madison, Wisconsin.

Guthrie, R. D.
1995 Mammalian Evolution in Response to Pleistocene-Holocene Transition and the Break-up of the Mammoth Steppe: Two Case Studies. *Acta Zoologica Cracovia* 38:139-154.

Hare, P. G., S. Greer, R. Gotthardt, R. Farnell, V. Bowyer, and C. Schweger
2004 Ethnographic and Archaeological Investigations of Alpine Ice Patches in Southwestern Yukon, Canada. *Arctic* 57(3):260-272.

Hemming, James E.
1971 *The Distribution, Movement Patterns of Caribou in Alaska*. Alaska Department of Fish and Game Technical Bulletin No. 1. Juneau, Alaska.

1975 Population Growth and Movement Patterns of the Nelchina Caribou Herd. *Proceedings of the First International Reindeer and Caribou Symposium* 1:162-169. Fairbanks, Alaska.

Hoffecker, J. F.
1988 Applied Geomorphology and Archaeological Survey Strategy for Sites of Pleistocene Age: An Example from Central Alaska. *Journal of Archaeological Science* 15:683-713.

Hoffecker, J. F., and S. A. Elias
2007 *Human Ecology of Beringia*. Columbia University Press, New York.

Hoffecker, J. F., W. R. Powers, and T. Goebel
1993 The Colonization of Beringia and the Peopling of the New World. *Science* 259:46-53.

Holliday, Vance T.
2004 *Soils in Archaeological Research.* Oxford University Press, Oxford.

Holmes, Charles E.
1996 Broken Mammoth. In *American Beginnings: The Prehistory and Paleoecology of Beringia*, edited by F.H. West, pp. 312-318. University of Chicago Press, Chicago.

2001 Tanana River Valley Archaeology Circa 14,000 to 9000 BP. *Arctic Anthropology* 38(2):154-170.

2011 The Beringian Transitional Period in Alaska: Technology of the East Beringian Tradition as Viewed from Swan Point. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia*, edited by Ted Goebel and Ian Buvit, pp. 179-191. Texas A&M University Press, College Station, Texas.

Holmes, Charles E., Richard VanderHoek, and Thomas E. Dilley
1996 Swan Point. In *American Beginnings: The Prehistory and Paleoecology of Beringia*, edited by Frederick Hadleigh West, pp. 319-323. University of Chicago Press, Chicago.

Holmes, Charles E., Joshua D. Reuther, and Peter Bowers
2010 The Eroadaway Site: Early Holocene Lithic Technological Variability in the Central Alaska Range. Paper presented at the 37th Annual Meeting of the Alaska Anthropological Association, Anchorage, Alaska.

Hotes, S., P. Poschlod, H. Takahashi, A. P. Grootjans, and E. Adema
2004 Effects of Tephra Deposition on Mire Vegetation: A Field Experiment in Hokkaido, Japan. *Journal of Ecology* 92(4):624-634.

Hu, Feng S., Linda B. Brubaker, and Patricia M. Anderson
1993 A 12,000 Year Record of Vegetation Change and Soil Development from Wien Lake, Central Alaska. *Canadian Journal of Botany* 71(9):1133-1142.

Hu, Feng S., Linda B. Brubaker, Daniel G. Gavin, Philip E. Higuera, Jason A. Lynch, T. S. Rupp, and Willy Tinner
2006 How Climate and Vegetation Influence the Fire Regime of the Alaskan Boreal Biome: The Holocene perspective. *Mitigation and Adaptation Strategies for Global Change* 11(4):829-846.

Hughes, P. D. M., G. Mallon, A. Brown, H. J. Essex, J. D. Stanford, and S. Hotes
2013 The Impact of High Tephra Loading on Late-Holocene Carbon Accumulation and Vegetation Succession in Peatland Communities. *Quaternary Science Reviews* 67:160-175.

Hunt, John B., and Peter G. Hill
1993 Tephra Geochemistry: A Discussion of Some Persistent Analytical Problems. *The Holocene* 3(3):271-278.

Hulten, Eric
1968 *Flora of Alaska and Neighboring Territories: A Manual of the Vascular Plants.* Stanford University Press, Palo Alto, California.

Irving, William, N.
1957 An Archaeological Survey of the Susitna Valley. *Anthropological Papers of the University of Alaska* 6(1):37-52.

Ito, Toyoaki, Sadao Shoji, Yasuhito Shirato, and Eri Ono
1991 Differentiation of a Spodic Horizon from a Buried A horizon. *Soil Science Society of America Journal* 55(2):438-442.

Ives, John W., Duane Froese, Kisha Supernant, and Gabriel Yanicki
2013 Vectors, Vestiges and Valhallas—Rethinking the Corridor. In *Paleoamerican Odyssey,* edited by Kelly E. Graf, Caroline V. Ketron and Michael R. Waters, pp. 149-169. Center for the Study of the First Americans, Texas A&M University, College Station, TX.

Jarosewich, Eugene, J. A. Nelen, and J. A. Norberg
1979 Electron Microprobe Reference Samples for Mineral Analyses. *Smithsonian Contributions to the Earth Sciences* 22:68-72.

Jarosewich, Eugene, J. A. Nelen, and Julie A. Norberg
1980 Reference Samples for Electron Microprobe Analysis. *Geostandards Newsletter* 4(1):43-47.

Johnson, J. D., L. J. Kershaw, Andy MacKinnon, and Jim Pojar
1995 *Plants of the Western Boreal Forest and Aspen Parkland.* Lone Pine Publishing, Edmonton.

Joly, Kyle, Bruce W. Dale, William B. Collins, and Layne G. Adams
2003 Winter Habitat Use by Female Caribou in Relation to Wildland Fires in Interior Alaska. *Canadian Journal of Zoology* 81(1192-1201).

Jones Miriam C., and Zicheng Yu
2010 Rapid Deglacial and Early Holocene Expansion of Peatlands in Alaska. *Proceedings of the National Academy of Sciences* 107(16):7347-7452

Juggins. S.
2007 C2 Version 1.5 User guide: Software for Ecological and Palaeoecological Data Analysis and Visualisation. Newcastle University, Newcastle upon Tyne, UK.

Kachadoorian, Reuben, David M. Hopkins, and Donald R. Nichols
1954 *A Preliminary Report of Geologic Factors Affecting Highway Construction in the Area Between the Susitna and MaClaren Rivers, Alaska.* U.S. Geological Survey Open File Report OF-92, U.S. Geological Survey, Juneau, Alaska.

Kapp, R. O., O. K. Davis, and J. E. King
2000 *Pollen and Spores*. The American Association of Stratigraphic Palynologists Inc. College Station, Texas.

Kari, J.
1977 Linguistic Diffusion between Tanaina and Ahtna. *International Journal of American Linguistics* 43(4):274-288

2008 *Ahtna Place Names Lists.* Alaska Native Language Center: Fairbanks, Alaska.

Kari, J., and J. A. Fall
2003 *Shem Pete's Alaska: The Territory of the Upper Cook Inlet Dena'ina*. University of Alaska Press.

Kelly, Robert L.
1983 Hunter-Gatherer Mobility Strategies. *Journal of Anthropological Research* 39(3):277-306.

1988 The Three Sides of a Biface. *American Antiquity* 53(4):717-734.

1992 Mobility/Sedentism: Concepts, Archaeological Measures, and Effects. *Annual Review of Anthropology,* 21:43-66.

1995 *The Foraging Spectrum.* Smithsonian Institution Press, Washington, D.C.

2001 *Prehistory of the Carson Desert and Stillwater Mountains*. Anthropological Paper 123, University of Utah Press.

Kintigh, Keith W.
1984 Measuring Archaeological Diversity by Comparison with Simulated Assemblages. *American Antiquity* 49(1):44-54.

Kuehn, S. C., D. G. Froese, P. A. R. Shane, and INTAV I. Participants
2011 The INTAV intercomparison of Electron-Beam Microanalysis of Glass by Tephrochronology Laboratories: Results and Recommendations. *Quaternary International* 246(1):19-47.

Kuhn, Steven L.
1990 A Geometric Index of Reduction for Unifacial Stone Tools. *Journal of Archaeological Science* (17):583-593.

1995 *Mousterian Lithic Technology: An Ecological Perspective*. Princeton University Press, Princeton.

Le Bas, Michael J., R. W. Le Maitre, Albert Streckeisen, and Bruno Zanettin
1986 A Chemical Classification of Volcanic Rocks Based on the Total Alkali-Silica Diagram. *Journal of Petrology* 27(3):745-750.

Lévesque, P. E. M., H. Dinel, and A. Larouche
1988 *Guide to the Identification of Plant Macrofossils in Canadian Peatlands.* Land Research Centre, Ottowa, Ontario.

Loso, Michael G.
2009 Summer Temperatures During the Medieval Warm Period and Little Ice Age Inferred from Varved Proglacial Lake Sediments in Southern Alaska. *Journal of Paleolimnology* 41(1):117-128.

Lotter, A. F, and H. J. B Birks
1993 The Impact of the Laacher See Tephra on Terrestrial and Aquatic Ecosystems in the Black Forest, Southern Germany. *Journal of Quaternary Science* 8(3):263-276.

Lowe, David J.
2011 Tephrochronology and its Application: A Review. *Quaternary Geochronology* 6(2):107-153.

Luedtke, Barbara E.
1992 *An Archaeologists Guide to Chert and Flint.* Archaeological Research Tools 7, Institute of Archaeology, University of California, Los Angeles.

Lynch, Jason A., Jeremy L. Hollis and Feng Sheng Hu
2004 Climatic and Landscape Controls of the Boreal Forest Fire Regime: Holocene Records from Alaska. Journal of Ecology 92(3):477-489.

MacDonald, G. M., K. V. Kremenetski and D. W. Beilman
2008 Climate Change and the Northern Russian Treeline Zone. *Philosophical Transactions of the Royal Society B* 363:2285-2299.

MacDonald, S. O., and Joseph A. Cook
2009 *Recent Mammals of Alaska*. University of Alaska Press, Fairbanks, Alaska.

Mann, Daniel H., Aron L. Crowell, Thomas D. Hamilton, and Bruce P. Finney
1998 Holocene Geologic and Climatic History Around the Gulf of Alaska. *Arctic Anthropology* 35(1):112-131.

Martin, Alexander C., and William D. Barkley
1961 *Seed Identification Manual.* University of California Press.

Mason, Owen K., and James E. Begét
1991 Late Holocene Flood History of the Tanana River, Alaska, USA. *Arctic and Alpine Research* 23(4):392-403.

Mason, Owen K., Peter M. Bowers, and David M. Hopkins
2001 The Early Holocene Milankovitch Thermal Maximum and Humans: Adverse Conditions for the Denali Complex of Eastern Beringia. *Quaternary Science Reviews* 20(1):525-548.

Mason, Owen K., and Nancy H. Bigelow
2008 The Crucible of Early to Mid-Holocene Climate in Northern Alaska: Does Northern Archaic Represent the People of the Spreading Forest? *Arctic Anthropology* 45(2):39-70.

Mauquoy, D., P. D. M Hughes, and B. Van Geel
2010 A protocol for plant macrofossil analysis of peat deposits. *Mires and Peat* 7(6):1-5.

Mauquoy, D., and B. Van Geel
2007 Mire and Peat Macros. In *Encyclopedia of Quaternary Science,* 1st ed. edited by Scott A. Elias and Cary J. Mock, pp. 2315-2336. Elsevier, Amsterdam.

McAndrews, John H., Albert A. Berti, and Geoffrey Norris
1973 *Key to the Quaternary Pollen and Spores of the Great Lakes Region*. Royal Ontario Museum Life Sciences Miscellaneous Publication, Ontario.

McDaniel, P. A., A. L. Falen, and M. A. Fosberg
1997 Genesis of Non-allophanic E Horizons in Tephra-Influenced Spodosols. *Soil Science Society of America Journal* 61(1):211-217.

Mitsch, William J. James G. Gosselink, Li Zhang, and Christopher J. Anderson
2009 *Wetland Ecosystems.* John Wiley & Sons, Hoboken, New Jersey

Moffit, Fred H.
1912 *Headwater Regions of Gulkana and Susitna Rivers Alaska: With Accounts of the Valdez Creek and Chistochina Placer Districts*. U.S. Geological Survey Bulletin 498. U.S. Geological Survey, Washington D.C.

Mooney, Philip Robert
2010 Geology of the Clearwater Mountains and the Southern Boundary of the Alaska Range Suture Zone. Unpublished MA Thesis, Department of Geology, University of California, Davis.

Moore, Peter D., Judith A. Webb, and Margaret E. Collison
1991 *Pollen Analysis.* Blackwell Scientific Publications, Oxford.

Moriya, Kikuo
1976 *Flora and Palynomorphs of Alaska.* Kodansha Corporation, Tokyo.

Mueller, Melissa Ann
2015 Taphonomy and Zooarchaeology of Faunal Assemblages from Archaeological Sites Along the Upper Susitna River, Alaska. Unpublished MA Thesis, Department of Anthropology, Texas A&M University.

Mullen, Patrick O.
2012 An Archaeological Test of the Effects of the White River Ash Eruptions. *Arctic Anthropology* 49(1):35-44.

Munsell Color
2009 *Munsell Rock Color Book*. Munsell Color, Grand Rapids, Michigan.

Murray, Andrew S., and Ann G. Wintle
2000 Luminescence Dating of Quartz Using an Improved Single-Aliquot Regenerative-Dose Protocol. *Radiation Measurements* 32(1):57-73.

Nelson, M. C.
1991 The Study of Technological Organization. In *Archaeological Method and Theory*, Vol. 3, edited by Michael Schiffer, pp. 57-100. University of Arizona Press, Tucson.

Nichols, Donald R.
1956 *Permafrost and Ground-Water Conditions in the Glennallen Area, Alaska.* U.S. Geological Survey Open File Report No. 56-91. U.S. Geological Survey, Washington, D.C.

Nowacki, Gregory J., Page Spencer, Michael Fleming, Terry Brock, and Torre Jorgenson
2001 *Ecoregions of Alaska and Neighboring Territories.* U.S. Geological Survey Open-File Report 02-297, U.S. Geological Survey, Washington, D.C.

Nowaczyk, Norbert
2001 Logging of Magnetic Susceptibility. In *Tracking Environmental Change using Lake Sediments*, *Volume 1 Basin Analysis, Coring, and Chronological Techniques,* edited by William A. Last and John P. Smol, pp 155-170. Kluwer Academic Press, Dordrecht.

O’Neill, J. Michael, Kenneth D. Ridgway, and Kevin R. Eastham
2001 *Mesozoic Sedimentation and Deformation Along the Talkeetna Thrust Fault, South-Central Alaska: New Insights and Their Regional Tectonic Significance*. U.S. Geological Survey Professional Paper 1678. U.S. Geological Survey, Washington, D.C.

Odell, George H.
1998 Investigating Correlates of Sedentism and Domestication in Prehistoric North America. *American Antiquity* 63(4):553-571.

2004 *Lithic Analysis*. Manuals in Archaeological Method, Theory and Technique, Springer, New York.

Parry, William J., and R. L. Kelly
1987 Expedient Core Technology and Sedentism. In *The Organization of Core Technology,* edited by J.K. Johnson and C.A. Morrow pp. 285-304, Westview Press, Boulder, Colorado.

Payne, Richard, and Jeffrey Blackford
2008 Distal Volcanic Impacts on Peatlands: Palaeoecological Evidence from Alaska. *Quaternary Science Reviews* 27(21):2012-2030.

Payne, Richard J., Kevin J. Edwards, and Jeff J. Blackford
2013 Volcanic Impacts on the Holocene Vegetation History of Britain and Ireland? A Review and Meta-analysis of the Pollen Evidence. *Vegetation History and Archaeobotany* 22(2):153-164.

Pearson, Georges A.
1999 Early Occupations and Cultural Sequence at Moose Creek: A Late Pleistocene Site in Central Alaska. *Arctic* 52:332-345.

Personius, S. F., A. J. Crone, P. A. Burns, J. E. Begét, G. G. Seitz, and S. P. Bemis
2010 *Logs and Geologic Data from a Paleoseismic Investigation of the Susitna Glacier Fault, Central Alaska Range, Alaska*. U.S. Geological Survey Scientific Investigations Map 3114, U.S. Geological Survey, Denver, CO.

Péwé, Troy L.
1975 *Quaternary Geology of Alaska.* U.S. Geological Survey Professional Paper 835. U.S. Geological Survey, Washington D.C.

Ping, C. L., S. Shoji, T. Ito, T. Takahashi, and J.P. Moore
1989 Characteristics and Classification of Volcanic-Ash-Derived Soils in Alaska. *Soil Science* 148(1):8-28.

Ping, C. L., G. J. Michaelson, J. M. Kimble, V. E. Romanovsky, Y. L. Shur, D. K. Swanson, and D. A. Walker
2008 Cryogenesis and Soil Formation Along a Bioclimate Gradient in Arctic North America. *Journal of Geophysical Research: Biogeosciences* 113(G03S12):1-14

Pitcher, Kenneth W.
1984 *Susitna Hydroelectric Project 1983 Annual Report, Big Game Studies Vol. IV: Caribou*. Alaska Department of Fish and Game. Submitted to the Alaska Power Authority, Report No. 2323.

Potter, Ben A.
2005 Site Structure and Organization in Central Alaska: Archaeological Investigations at Gerstle River. Unpublished Ph.D. dissertation, Department of Anthropology, University of Alaska, Fairbanks.

2008a Radiocarbon Chronology of Central Alaska: Technological Continuity and Economic Change. *Radiocarbon* 50(2):181-204.

2008b Exploratory Models of Intersite Variability in Mid to Late Holocene Central Alaska. *Arctic* :407-425.

2008c A First Approximation of Interassemblage Variability in Central Alaska. *Arctic Anthropology* 45(2):88-112.

2011 Late Pleistocene and Early Holocene Assemblage Variability in Central Alaska. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability in Late Pleistocene/Early Holocene Beringia*, edited by Ted Goebel and Ian Buvit, pp. 215-233. Texas A&M University Press, College Station, Texas.

Potter, Ben A., Joel D. Irish, Joshua D. Reuther, Carol Gelvin-Reymiller, and Vance T. Holliday
2011 A Terminal Pleistocene Child Cremation and Residential Structure from Eastern Beringia. *Science* 331:1058-1062.

Potter, Ben A., Charles E. Holmes, and David R. Yesner
2014 Technology and Economy among the Earliest Prehistoric Foragers in Interior Eastern Beringia. In: *Paleoamerican Odyssey*, edited by Kelly E. Graf, Caroline V. Ketron, and Michael R. Waters, pp. 81-103. Texas A&M University Press, College Station.

Pouchou, J. L., and R. Pichoir
1985 “PAP” (phi-rho-z) Procedure for Improved Quantitative Microanalysis. In *Microbeam Analysis,* edited by J. T. Armstrong, pp. 104-106. San Francisco Press, San Francisco.

Powers, W. Roger, and John F. Hoffecker
1989 Late Pleistocene Settlement in the Nenana Valley, Central Alaska. *American Antiquity* 54(2):263-287.

Proctor, Paul Dean, P. Robert Peterson, and Uwe Kackstaetter
1989 *Mineral-Rock Handbook: Rapid-Easy Mineral-Rock Determination*. Paulmar Publishers, Sandy Utah.

Ramsey, C. B.
2009 Bayesian Analysis of Radiocarbon Dates. *Radiocarbon* 51(1):337-360.

Rasic, Jeffery Thomas
2008 Paleoalaskan Adaptive Strategies Viewed From Northwestern Alaska. Unpublished PhD. Dissertation, Department of Anthropology, Washington State University, Pullman, WA.

Rasic, Jeff, and Willam Andrefsky Jr.
2001 Blade Cores and Technological Organization in Northwestern North America. In *Lithic Debitage Analysis: Context Form Meaning*, edited by William Andrefsky, Jr., pp. 233-258, University of Utah Press, Salt Lake City.

Rasmussen, S. O., K. K. Andersen, A. M. Svensson, J. P. Steffensen, B. M. Vinther, H. B. Clausen, M. L. Siggaard-Andersen, S. J. Johnsen, L. B. Larsen, D. Dahl-Jensen, M. Bigler, R. Röthlisberger, H. Fischer, K. Goto-Azuma, M. E. Hansson, and U. Ruth
2006 A new Greenland Ice Core Chronology for the Last Glacial Termination. *Journal Of Geophysical Research* 111(D06102):1-16

Rautio, M., and L. Nevalainen
2007 Cladocera. In *Encyclopedia of Quaternary Science,* 1st edition, edited by Scott A. Elias and Cary J. Mock, pp. 2029-2038. Elsevier, Amsterdam.

Reckin, Rachel
2011 Of Ice and Men: Archaeological Discoveries from Alpine Ice Patches Worldwide and their Relationship with Paleoclimates. Unpublished M.A. thesis, Department of Anthropology, University of Wyoming.

Reckord, Holly
1983 *Where Raven Stood: Cultural Resources of the Ahtna Region.* Anthropology and Historic Preservation Cooperative Park Studies Unit, Occasional Paper No.35, University of Alaska, Fairbanks.

Reger, R. D., and Bundtzen, T. K.
1990 *Multiple Glaciation and Gold-Placer Formation, Valdez Creek Valley, Western Clearwater Mountains, Alaska*. Division of Geological and Geophysical Surveys Professional Report 107. Department of Natural Resources, Anchorage.

Reger, Richard D., Thomas K. Bundtzen, and Thomas E. Smith
1990 *Geology of the Healy A-3 Quadrangle, Alaska.* Division of Geological and Geophysical Surveys Public-data File 90-1. Department of Natural Resources, Fairbanks.

Reger, Richard D., Thomas Lowell, and Edward B. Evenson
2011 Discussion of "Late Quaternary megafloods from Glacial Lake Atna, Southcentral Alaska, USA". *Quaternary Research* 75(1):301-302.

Reimer, Paula J., Edouard Bard, Alex Bayliss, J. W. Beck, Paul G. Blackwell, Christopher Bronk Ramsey, Caitlin E. Buck, Hai Cheng, R. L. Edwards, and Michael Friedrich
2013 IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years Cal BP. *Radiocarbon* 55(4):1869–1887.

Reuther, Joshua D.
2013 Late Glacial and Early Holocene Geoarchaeology and Terrestrial Paleoecology in the Lowlands of the Middle Tanana Valley, Subarctic Alaska. Unpublished PhD Dissertation, Department of Anthropology, University of Arizona, Tuscon.

Reuther, Joshua D., Natalia S. Slobodina, Jeffrey T. Rasic, John P. Cook, and Robert J. Speakman
2011 Gaining Momentum: Late Pleistocene and Early Holocene Archaeological Obsidian Source Studies in Interior and Northeastern Beringia. In *From the Yenisei to the Yukon: Interpreting Lithic Assemblage Variability on Late Pleistocene/Early Holocene Beringia,* edited by Ted Goebel and Ian Buvit, pp. 270-288. Texas A&M University Press, College Station.

Riehle, J. R.
1985 A Reconnaissance of the Major Holocene Tephra Deposits in the Upper Cook Inlet region, Alaska. *Journal of Volcanology and Geothermal Research* 26(1-2):37-74.

Ritchie, J. C.
1995 Current Trends in Studies of Long-term Plant Community Dynamics. *New Phytologist* 130(4):469-494.

Riehle, James R.
2000 Correlation of Tephra Deposits on the Basis of Chemical Similarity: An Idealised Conceptual Model Subject to Multiple Sources of Uncertanity. In *Capricious Earth: Models and Modeling of Geologic Processes and Objects,* edited by Glebovitsky V. A. and Dech V. N., pp. 887-100. Theophrastus Publications, St. Petersburg and Athens.

Robinson, Brian S.
2008 Microblades and Seasonality: Settlement Patterns in the Tangle Lakes Region. *The Review of Archaeology* 29:21-40.

Rohr, M.
2001 Paleoenvironmental Changes at Treeline in Central Alaska: A 6.500 Year Long Pollen and Stable Isotope Record. Unpublished M.A. thesis, Department of Geology & Geophysics, University of Alaska, Fairbanks.

Romick, Jay D., and Robert M. Thorson
1983 *Petrography and Stratigraphy of Holocene Tephra from the Susitna Canyon Area, South-Central Alaska.* Manuscript on file, University of Alaska Museum of the North.

Rubin, Meyer, and Corrinne Alexander
1960 U.S. Geological Survey Radiocarbon Dates V. *Radiocarbon* 2(1):129-185.

Sarna-Wojcicki, Andrei
2000 Tephrochronology. In *Quaternary Geochronology: Methods and Applications,* edited by Jay S. Noller, Janet M. Sowers and William R. Lettis, pp. 357-377. Wiley, Hoboken, New Jersey.

Schaetzl, R. J., and S. Anderson
2005 *Soils: Genesis and Geomorphology.* Cambridge University Press, New York.

Schunke, Ekkehard, and S. C. Zoltai
1988 Earth Hummocks (Thufur). In *Advances in Periglacial Geomorphology,* edited by M. J. Clark, pp. 231-245. John Wiley & Sons Limited, Chichester.

Schwanke, Rebecca
2011 *Game Management Unit 13, Nelchina Caribou Herd*. Alaska Department of Fish and Game, Anchorage.

Schweger, Charles E.
1981 Chronology of Late Glacial Events from the Tangle Lakes, Alaska Range, Alaska. *Arctic Anthropology* 18(1):97-101.

Seppä, Heikki, and Sheila Hicks
2006 Integration of Modern and Past Pollen Accumulation Rate (PAR) Records Across the Arctic Tree-line: A Method for More Precise Vegetation Reconstructions. *Quaternary Science Reviews* 25:1501–1516.

Seppä, Heikki
2007 Pollen Analysis, Principles. In *Encyclopedia of Quaternary Science,* 1st ed. edited by Scott A. Elias and Cary J. Mock, pp. 2486-2497. Elsevier, Amsterdam.

Seppälä, Matti
2004 *Wind as a Geomorphic Agent in Cold Climates.* Cambridge University Press, Cambridge.

Shane, Phil
2000 Tephrochronology: a New Zealand Case Study. *Earth-Science Reviews* 49(1):223-259.

Shott, Michael J.
1986 Technological Organization and Settlement Mobility: An Ethnographic Examination. *Journal of Anthropological Research* 42:15-51.

Shulski, Martha, and Gerd Wendler
2007 *The Climate of Alaska.* University of Alaska Press, Fairbanks.

Simeone, William E.
2006 *Some Ethnographic and Historical Information on the Use of Large Land Mammals in the Copper River Basin*. Alaska Region Technical Report Series Cultural Resources Report NPS/AR/CRR-2006-56. National Park Service, Department of the Interior, Copper Center, Alaska.

2008 *Customary and Traditional Use Worksheets: Upper Copper and Upper Susitna River Area Nonsalmon Finfish Species and Prince William Sound Salmon*. Special Publication No. BOF 2008-11. Alaska Department of Fish and Game, Anchorage.

Skarland, Ivar, and Charles J. Keim
1958 Archaeological Discoveries on the Denali Highway, Alaska. *Anthropological Papers of the University of Alaska* 6(2):79-88.

Skeete, Luanda K.
2008 An Analysis of Faunal Remains from the Susitna Hydroelectric Project. Unpublished MA Thesis, Department of Anthropology, University of Alaska Fairbanks, Fairbanks, Alaska.

Skoog, Ronald Oliver
1968 Ecology of the Caribou (Rangifer Tarandus Granti) in Alaska. Unpublished PhD dissertation, Department of Zoology, University of California, Berkley.

Smith, T. E., M. D. Albanese, and G. L. Kline
1988 *Geologic Map of the Healy A-2 Quadrangle, Alaska*. Alaska Division of Geological & Geophysical Surveys, Professional Report 95. Department of Natural Resources, Fairbanks.

Smith, T. E.
1981 Geology of the Clearwater Mountains, South-Central Alaska. Alaska Division of Geological & Geophysical Surveys Geologic Report 60. Alaska Department of Natural Resources, College, Alaska.

Soil Survey Staff
1999 *Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys.* Agriculture Handbook Number 436, 2nd ed. United States Department of Agriculture Natural Resources Conservation Service, Washington D.C.

Stein, Julie K.
1984 Organic Matter and Carbonates in Archaeological Sites. *Journal of Field Archaeology* 11(2):239-246.

Stockmarr, Jens
1972 Tablets with Spores Used in Absolute Pollen Analysis. *Pollen et Spores* 13:615-621.

Surovell, Todd Alexander
2003 *The Behavioral Ecology of Folsom Lithic Technology*. Unpublished Ph.D. Dissertation, Department of Anthropology, University of Arizona, Tuscon.

2009 *Toward A Behavioral Ecology of Lithic Technology: Cases from Paleoindian Archaeology*. The University of Arizona Press, Tuscon.

Tobey, B. and R. Schwanke
2009 Units 13 and 14B Caribou Management Report. In *Caribou Management Report of Survey and Inventory Activities 1 July 2006-30 June 2008*, edited by P. Harper, pp 83-89. Alaska Department of Fish and Game, Juneau, Alaska.

VanderHoek, Richard
2009 The Role of Ecological Barriers in the Development of Cultural Boundaries During the Later Holocene of the Central Alaska Peninsula. Unpublished Ph.D. Dissertation, Department of Anthropology, University of Illinois at Urbana-Champaign, Urbana.

2011 *Cultural Resource Management Plan for the Denali Highway Lands, Central Alaska.* Office of History and Archaeology Report Number 112, Alaska Office of History and Archaeology, Anchorage, Alaska.

Vanderhoek, Richard, and R. E. Nelson
2007 Ecological Roadblocks on a Constrained Landscape: The Cultural Effects of Catastrophic Holocene Volcanism on the Alaska Peninsula, Southwest Alaska. In *Living Under The Shadow: Cultural Impacts of Volcanic Eruptions,* edited by John Grattan and Robin Torrence, pp. 133-152. Left Coast Press, Walnut Creek, CA.

VanderHoek, R., R. M. Tedor, C. E. Holmes, and D. McMahan
2007a Cultural Materials Recovered from Ice Patches in the Denali Highway Region, Central Alaska, 2003-2005. *Alaska Journal of Anthropology* 5(2):175-200.

VanderHoek, R., B. T. Wygal, R. Tedor, and C. E. Holmes
2007b Survey and Monitoring of Ice Patches in the Denali Highway Region, Central Alaska, 2003-2005. *Alaska Journal of Anthropology* 5(2):67-86.

Wahrhaftig, C.
1960 *The Physiographic Provinces of Alaska*. U.S. Geological Survey Open-File Report 60-146, U.S. Geological Survey, Washington, D.C.

1965 *Physiographic Divisions of Alaska.* U.S. Geological Survey Professional Paper 482, U.S. Geological Survey, Washington, D.C.

Walker, I. R.
2007 Overview of Fossil Chironomids. In *Encyclopedia of Quaternary Science,* 1st ed. edited by Scott A. Elias pp 360-366. Elsevier, Amsterdam.

Wallace, Kristi L., Michelle L. Coombs, Leslie A. Hayden, and Christopher F. Waythomas
2014 *Significance of a Near-Source Tephra-Stratigraphic Sequence to the Eruptive History of Hayes Volcano, South-Central Alaska.* Scientific Investigations Report 2014-5133, U.S. Geological Survey, Washington, D.C.

Wang, Qingren, Yuncong Li, and Y. Wang
2011 Optimizing the Weight Loss-on-ignition Methodology to Quantify Organic and Carbonate Carbon of Sediments from Diverse Sources. *Environmental Monitoring and Assessment* 174(1-4):241-257.

Waters, Michael R.
1992 *Principles of Geoarchaeology: a North American Perspective.* University of Arizona Press, Tuscon.

Wendt, M. L.
2013 Integrating Climate Change with Human Land Use Patterns: Archaeology of Butte Lake Northeast. Unpublished MA Thesis, Department of Anthropology, University of Alaska, Fairbanks.

Wentworth, Chester K.
1922 A Scale of Grade and Class Terms for Clastic Sediments. *The Journal of Geology,* 30(5):377-392.

West, Frederick H., Brian S. Robinson, and Mary Lou Curran
1996a Phipps Site. In *American Beginnings: The Prehistory and Paleoecology of Beringia*, edited by F.H. West, pp. 381-386. University of Chicago Press, Chicago.

West, Frederick H., Brian S. Robinson, and R. Greg Dixon
1996b Sparks Point. In *American Beginnings: The Prehistory and Paleoecology of Beringia*, edited by F.H. West, pp. 394-398. University of Chicago Press, Chicago.

West, Frederick H., Brian S. Robinson, and Constance F. West
1996c Whitmore Ridge. In *American Beginnings: The Prehistory and Paleoecology of Beringia*, edited by F.H. West, pp. 386-394. University of Chicago Press, Chicago.

White, J. D. L, and B. F. Houghton
2006 Primary Volcaniclastic Rocks. *Geology* 34(8):677-680.

Wiedmer, Michael, David R. Montgomery, Alan R. Gillespie, and Harvey Greenberg
2010 Late Quaternary Megafloods from Glacial Lake Atna, Southcentral Alaska, USA. *Quaternary Research* 73(3):413-424.

Williams, John R., and John P. Galloway
1986 *Map of Western Copper River Basin, Alaska, Showing Lake Sediments and Shorelines, Glacial Moraines, and Location of Stratigraphic Sections and Radiocarbon-dated Samples.* U.S. Geological Survey Open-File Report 86-390, U.S. Geological Survey, Washington.

Williams, John R.
1989 A Working Glacial Chronology for the Western Copper River Basin, Alaska. In *Late Cenozoic History of the Interior Basins of Alaska and the Yukon.* Vol. 1026, edited by L. D. Carter, Thomas D. Hamilton and John P. Galloway, pp. 81-84. US Geological Survey, Washington D.C.

Woodward-Clyde Consultants
1982 *Alaska Power Authority Susitna Hydroelectric Project: Final Report on Seismic Studies for Susitna Hydroelectric Project (Subtasks 4.09-4.15).* Acres American Incorporated, Buffalo.

Wygal, Brian T.
2009 The Prehistoric Colonization of Southcentral Alaska: Human Adaptations in a Post Glacial World. Unpublished Ph.D. dissertation, Department of Anthropology, University of Nevada, Reno.

2010 Prehistoric Upland Tool Production in the Central Alaska Range. *Alaska Journal of Anthropology* 8(1):107-119.

Yesner, David R.
2001 Human Dispersal into Interior Alaska: Antecedent Conditions, Mode of Colonization, and Adaptations. *Quaternary Science Reviews* 20(1):315-327.

Zoltai, S. C., S. J. Taylor, J. K. Jeglum, G. F. Mills, and J. D. Johnson
1988 Wetlands of Boreal Canada. In *NWWG-CCELC. (National Wetlands Working Group-Canada Committee on Ecological Land Classification) Wetlands of Canada,* Ecological Land Classification Series No. 24, Environment Canada, Sustainable Development Branch, Ottawa.

APPENDIX A

Table 38. Published EPMA comparative data.

Sample	Correlated tephra		SiO_2	TiO_2	Al_2O_3	FeO_T	Mn	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$Total_{raw}$[1]	n	Reference
27-A	Hayes-correlated late Holocene (Devil?)	mean	73.79	0.30	14.61	1.86[2]	0.06	0.49	2.22	3.73	2.76	—	—	93.10	—	Riehle 1985[7]
		1 σ	2.10	0.06	0.90	0.25	0.05	0.06	0.19	0.21	0.12	—	—			
Devil	Devil tephra (informal)	mean	73.91	0.26	14.69	1.71[2]	—	0.51	2.17	3.70	2.52	0.34	—	97.95	—	Romick, 1984 (in Dilley 1988)
		1 σ	1.79	0.08	0.28	0.27	—	0.07	0.18	0.27	0.08	0.06	—			
ATC-633	Jarvis Ash Bed	mean	73.65	0.23	14.50	1.75[2]	—	0.54	2.23	3.93	2.62	0.36	—	—	15	Begét et al. 1991
		1 σ	0.36	0.03	0.14	0.21	—	0.03	0.10	0.08	0.11	0.03	—			
ATC-634	Jarvis Ash Bed	mean	73.71	0.23	14.54	1.67[2]	—	0.53	2.23	3.94	2.61	0.35	—	—	18	Begét et al. 1991
		1 σ	0.36	0.04	0.19	0.14	—	0.05	0.13	0.13	0.06	0.05	—			
ATC-635	Jarvis Ash Bed	mean	73.67	0.23	14.61	1.69[2]	—	0.55	2.23	2.89	2.58	0.35	—	—	17	Begét et al. 1991
		1 σ	0.58	0.11	0.25	0.19	—	0.05	0.15	0.15	0.08	0.04	—			
ATC-636	Jarvis Ash Bed	mean	73.41	0.24	14.66	1.75[2]	—	0.55	2.31	3.92	2.61	0.37	—	—	19	Begét et al. 1991
		1 σ	0.50	0.03	0.21	0.17	—	0.05	0.11	0.11	0.10	0.04	—			
ATC-637	Jarvis Ash Bed	mean	73.67	0.24	14.64	1.67[2]	—	0.54	2.25	3.93	2.59	0.37	—	—	11	Begét et al. 1991
		1 σ	0.53	0.04	0.12	0.21	—	0.07	0.10	0.10	0.07	0.05	—			
ATC-638-P1	Cantwell ash bed (informal)	mean	73.69	0.24	14.42	1.71[2]	—	0.49	2.25	3.97	2.57	0.43	—	—	5	Begét et al. 1991
		1 σ	0.33	0.04	0.09	0.07	—	0.06	0.10	0.07	0.07	0.04	—			
ATC-638-P2	Cantwell ash bed (informal) [4]	mean	74.54	0.21	14.22	1.49[2]	—	0.49	2.01	3.91	2.60	0.36	—	—	7	Begét et al. 1991
		1 σ	0.22	0.06	0.12	0.13	—	0.03	0.05	0.15	0.04	0.02	—			
ATC-639	Cantwell ash bed (informal)	mean	73.64	0.25	14.65	1.75[2]	—	0.54	2.23	3.82	2.56	0.37	—	—	11	Begét et al. 1991
		1 σ	0.34	0.02	0.15	0.11	—	0.04	0.01	0.08	0.06	0.04				
ATC-640	Cantwell ash bed (informal) [5]	mean	73.75	0.24	14.50	1.71[2]	—	0.53	2.25	3.91	2.57	0.35	—	—	16	Begét et al. 1991
		1 σ	0.47	0.04	0.21	0.15	—	0.04	0.13	0.13	0.06	0.05	—			
ATC-641	Cantwell ash bed (informal)	mean	73.59	0.22	14.65	1.71[2]	—	0.53	2.25	3.91	2.60	0.35	—	—	15	Begét et al. 1991
		1 σ	0.39	0.03	0.28	0.16	—	0.07	0.13	0.17	0.10	0.03	—			

Table 38 (Continued)

Sample	Correlated tephra		SiO_2	TiO_2	Al_2O_3	FeO_T	Mn	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$Total_{raw}$[1]	n	Reference
ATC-642-P1	Cantwell ash bed (informal) [5]	mean	73.32	0.24	14.69	1.74[2]	—	0.61	2.35	3.89	2.60	0.37	—	—	10	Begét et al. 1991
		1 σ	0.22	0.20	0.20	0.12	—	0.14	0.09	0.10	0.09	0.05	—			
ATC-642-P2	Cantwell ash bed (informal) [4]	mean	72.57	0.26	14.92	1.89[2]	—	0.65	2.43	3.98	2.72	0.37	—	—	11	Begét et al. 1991
		1 σ	0.43	0.03	0.39	0.26	—	0.14	0.34	0.12	0.35	0.07	—			
ATC-643	Cantwell ash bed (informal)	mean	73.66	0.23	14.59	1.69[2]	—	0.54	2.25	3.91	2.58	0.37	—	—	16	Begét et al. 1991
		1 σ	0.35	0.04	0.13	0.13	—	0.04	0.11	0.12	0.07	0.04	—			
88-TL-CC	Tangle Lakes tephra (informal)	mean	73.56	0.22	14.63	1.82[2]	—	0.53	2.28	3.90	2.54	0.32	—	—	13	Begét et al. 1991
		1 σ	0.35	0.07	0.21	0.18	—	0.05	0.09	0.12	0.10	0.01	—			
TL-3	Tangle Lakes tephra (informal)	mean	73.80	0.24	14.61	1.67[2]	—	0.53	2.31	3.77	2.50	0.38	—	—	13	Begét et al. 1991
		1 σ	0.38	0.04	0.16	0.16	—	0.04	0.10	0.11	0.07	0.05	—			
TL-7	Tangle Lakes tephra (informal)	mean	73.84	0.25	14.55	1.76[2]	—	0.52	2.25	3.79	2.46	0.37	—	—	5	Begét et al. 1991
		1 σ	0.47	0.04	0.14	0.22	—	0.10	0.10	0.17	0.06	0.03	—			
TL-8	Tangle Lakes tephra (informal)	mean	73.81	0.27	14.46	1.78[2]	—	0.50	2.20	3.81	2.63	0.34	—	—	15	Begét et al. 1991
		1 σ	0.40	0.07	0.33	0.17	—	0.05	0.27	0.13	0.45	0.09	—			
TL-9	Tangle Lakes tephra (informal)	mean	73.73	0.22	14.58	1.72[2]	—	0.53	2.30	3.82	2.53	0.36	—	—	14	Begét et al. 1991
		1 σ	0.57	0.03	0.21	0.20	—	0.07	0.17	0.11	0.12	0.06	—			
ACT-4002	Jarvis Creek Ash[3]	mean	73.39	0.21	14.29	1.60[2]	—	0.58	2.33	4.29	2.76	0.37	—	—	10	Personius et al. 2010
		1 σ	0.75	0.17	0.72	0.11	—	0.08	0.18	0.48	0.20	0.07	—			
ACT-4003	Jarvis Creek Ash[3]	mean	73.60	0.20	14.48	1.44[2]	—	0.51	2.21	4.31	2.78	0.31	—	—	11	Personius et al. 2010
		1 σ	0.42	0.18	0.36	0.38	—	0.13	0.16	0.29	0.36	0.09	—			
ACT-4004	Jarvis Creek Ash[3]	mean	73.52	0.26	14.55	1.55[2]	—	0.59	2.19	3.97	2.84	0.36	—	—	12	Personius et al. 2010
		1 σ	0.60	0.23	0.33	0.23	—	0.10	0.20	0.40	0.22	0.04	—			
ACT-4005	Jarvis Creek Ash[3]	mean	73.64	0.26	14.80	1.65[2]	—	0.56	2.31	3.92	2.80	0.34	—	—	13	Personius et al. 2010
		1 σ	0.67	0.21	0.39	0.34	—	0.09	0.26	0.26	0.19	0.08	—			

Table 38 (Continued)

Sample	Correlated tephra		SiO_2	TiO_2	Al_2O_3	FeO_T	Mn	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	Total$_{raw}$[1]	n	Reference
ACT-4005b	Jarvis Creek Ash[3]	mean	73.64	0.16	14.57	1.57[2]	—	0.53	2.21	3.92	2.86	0.36	—	—	13	Personius et al. 2010
		1 σ	0.80	0.22	0.52	0.34	—	0.16	0.26	0.26	0.19	0.08	—			
ACT-4006	Jarvis Creek Ash[3]	mean	73.61	0.21	14.24	1.65[2]	—	0.54	2.20	4.24	2.78	0.35	—	—	23	Personius et al. 2010
		1 σ	0.58	0.18	0.40	0.14	—	0.06	0.15	0.31	0.13	0.06	—			
ACT-4007	Jarvis Creek Ash[3]	mean	73.51	0.18	14.64	1.59[2]	—	0.52	2.21	4.02	2.79	0.35	—	—	26	Personius et al. 2010
		1 σ	0.82	0.18	0.40	0.27	—	0.11	0.17	0.44	0.12	0.04	—			
ACT-4008	Jarvis Creek Ash[3]	mean	73.70	0.20	14.29	1.65[2]	—	0.55	2.16	4.08	2.85	0.34	—	—	20	Personius et al. 2010
		1 σ	0.74	0.20	0.46	0.19	—	0.13	0.20	0.47	0.15	0.04	—			
23-A	Riehle 23-A	mean	75.41	0.24	13.80	1.72	0.06	0.53	2.29	3.45	2.44	—	—	96.40	6	Riehle 1994[7]
		1 σ[6]	2.76	—	0.44	0.25	—	0.25	7.40	5.30	3.90	—	—			
23-B	Riehle 23-B	mean	76.63	0.22	13.44	1.23	0.05	0.28	1.93	3.39	2.84	—	—	96.70	10	Riehle 1994[7]
		1 σ[6]	3.50	—	0.04	9.80	—	40.00	13.00	5.20	14.00	—	—			
23-C	Riehle 23-C	mean	74.48	0.24	14.64	1.63	0.04	0.49	2.22	3.64	2.59	—	—	95.60	8	Riehle 1994[7]
		1 σ[6]	3.40	—	0.03	6.20	—	9.00	4.80	3.70	2.30	—	—			
23-D	Riehle 23-D	mean	72.94	0.27	14.88	1.99	0.05	0.70	2.86	3.81	2.46	—	—	96.10	6	Riehle 1994[7]
		1 σ[6]	1.60	—	0.04	17.00	—	38.00	26.00	5.30	5.20	—	—			
23-E1	Riehle 23-E1	mean	74.52	0.25	14.41	1.83	0.06	0.53	2.23	3.44	2.74	—	—	93.00	9	Riehle 1994[7]
		1 σ[6]	5.20	—	0.04	8.60	—	21.00	18.00	5.90	12.00	—	—			
23-E2	Riehle 23-E2	mean	71.70	0.24	16.04	1.84	0.06	0.67	3.22	3.84	2.34	—	—	95.40	2	Riehle 1994[7]
		1 σ[6]	1.30	—	0.01	23.00	—	30.00	8.50	3.10	0.00	—	—			
23-F	Riehle 23-F	mean	76.51	0.21	13.69	1.13	0.04	0.22	1.79	3.63	2.82	—	—	97.90	9	Riehle 1994[7]
		1 σ[6]	2.30	—	0.05	20.00	—	41.00	19.00	8.30	13.00	—	—			
23-G	Riehle 23-G	mean	74.84	0.25	14.53	1.69	0.04	0.50	2.25	3.68	2.23	—	—	92.20	7	Riehle 1994[7]
		1 σ[6]	7.30	—	0.09	24.00	—	29.00	23.00	9.50	14.00	—	—			
Upper Watana	upper Watana tephra (informal)	mean	74.34	0.19	14.77	1.98[2]	—	0.52	2.31	3.41	2.55	0.35	—	96.57	—	Romick, 1984 (in Dilley 1988)
		1 σ	1.22	0.05	0.41	0.36	—	0.16	0.27	0.20	0.07	0.06	—			

Table 38 (Continued)

Sample	Correlated tephra		SiO_2	TiO_2	Al_2O_3	FeO_T	Mn	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	$Total_{raw}$[1]	n	Reference
Lower Watana	lower Watana tephra (informal)	mean	73.73	0.20	14.83	1.75[2]	—	0.50	2.26	3.64	2.55	0.35	—	97.89	—	Romick, 1984 (in Dilley 1988)
		1 σ	1.72	0.04	0.26	0.19	—	0.04	0.16	0.21	0.08	0.05	—			
AT-2558-P1	III: tephra A	mean	70.84	0.34	15.87	2.18	0.11	0.72	2.97	4.40	2.10	0.34	0.13	97.16	12	Wallace et al. 2014
		1 σ	0.24	0.05	0.17	0.13	0.05	0.04	0.07	0.19	0.06	0.04	0.03			
AT-2558-P2	III: tephra A	mean	76.50	0.05	14.65	0.56	0.20	0.11	0.64	3.47	3.58	0.12	0.13	93.02	10	Wallace et al. 2014
		1 σ	0.51	0.03	0.33	0.13	0.04	0.03	0.05	0.13	0.32	0.03	0.03			
AT-2558-P3	III: tephra A	mean	72.38	0.24	15.38	1.74	0.09	0.53	2.49	4.07	2.65	0.37	0.06	97.03	4	Wallace et al. 2014
		1 σ	0.25	0.05	0.22	0.12	0.06	0.01	0.05	0.16	0.07	0.06	0.03			
AT-2559	III: tephra B	mean	72.83	0.27	15.09	1.81	0.09	0.57	2.52	4.27	2.18	0.29	0.08	98.38	27	Wallace et al. 2014
		1 σ	0.44	0.04	0.31	0.13	0.04	0.04	0.10	0.20	0.07	0.05	0.04			
AT-2560-P1	III: tephra F1	mean	71.33	0.29	15.70	1.90	0.10	0.59	2.56	4.32	2.68	0.46	0.07	95.11	12	Wallace et al. 2014
		1 σ	0.29	0.06	0.23	0.08	0.02	0.03	0.09	0.14	0.06	0.05	0.03			
AT-2560-P2	III: tephra F1	mean	72.56	0.28	15.11	1.84	0.09	0.56	2.39	4.10	2.58	0.40	0.08	96.79	9	Wallace et al. 2014
		1 σ	0.14	0.03	0.15	0.09	0.02	0.03	0.07	0.15	0.06	0.05	0.03			
AT-2561	III: tephra F2	mean	74.14	0.21	14.49	1.51	0.09	0.47	2.12	3.93	2.66	0.33	0.06	97.24	29	Wallace et al. 2014
		1 σ	0.46	0.05	0.20	0.10	0.04	0.04	0.11	0.17	0.08	0.04	0.03			
AT-2562-P1	III: tephra G	mean	77.75	0.27	12.17	1.32	0.09	0.25	1.36	3.43	2.87	0.45	0.05	94.79	26	Wallace et al. 2014
		1 σ	0.86	0.04	0.60	0.12	0.03	0.03	0.27	0.23	0.15	0.06	0.03			
AT-2562-P2	III: tephra G	mean	74.59	0.19	14.44	1.16	0.08	0.20	2.47	3.90	2.48	0.44	0.05	97.19	2	Wallace et al. 2014
		1 σ	0.32	0.05	0.29	0.04	0.02	0.01	0.23	0.17	0.05	0.06	0.00			
AT-2563-P1	III: tephra H1	mean	65.24	0.50	16.48	3.90	0.11	2.00	5.04	4.43	1.84	0.21	0.24	99.48	17	Wallace et al. 2014
		1 σ	0.41	0.06	0.21	0.16	0.04	0.05	0.19	0.18	0.06	0.03	0.04			
AT-2563-P2	III: tephra H1	mean	75.07	0.20	13.75	1.59	0.07	0.39	2.05	3.78	2.66	0.39	0.05	96.27	12	Wallace et al. 2014
		1 σ	0.56	0.04	0.25	0.12	0.03	0.02	0.14	0.24	0.11	0.07	0.04			

Table 38 (Continued)

Sample	Correlated tephra		SiO_2	TiO_2	Al_2O_3	FeO_T	Mn	MgO	CaO	Na_2O	K_2O	Cl	P_2O_5	Total$_{raw}$[1]	n	Reference
AT-2564	III: tephra H2	mean	75.36	0.22	13.73	1.61	0.08	0.42	2.06	3.51	2.57	0.40	0.05	97.32	25	Wallace et al. 2014
		1 σ	0.61	0.04	0.33	0.18	0.04	0.04	0.18	0.29	0.13	0.06	0.03			
AT-2565	III: tephra E	mean	72.69	0.29	14.76	1.87	0.10	0.59	2.36	4.02	2.79	0.44	0.09	97.03	17	Wallace et al. 2014
		1 σ	0.62	0.05	0.18	0.07	0.03	0.06	0.12	0.55	0.18	0.05	0.04			
AT-2567	III: tephra D	mean	73.64	0.21	14.77	1.48	0.08	0.45	2.04	4.35	2.61	0.31	0.07	95.13	15	Wallace et al. 2014
		1 σ	0.97	0.07	0.45	0.19	0.03	0.06	0.19	0.26	0.14	0.05	0.04			
ACT-1073	Oshetna (informal)	mean	72.81	0.32	14.85	1.95[2]	—	0.56	2.35	4.06	2.82	0.20	—	96.79	8	Child et al. 1998
		1 σ	0.37	0.15	0.38	0.46	—	0.24	0.08	0.38	0.28	0.09	—			
ACT-1076	Oshetna (informal)	mean	72.71	0.39	14.91	1.97[2]	—	0.64	2.26	4.05	2.66	0.20	—	95.80	17	Child et al. 1998
		1 σ	1.93	0.12	1.43	0.75	—	0.57	0.54	0.68	0.37	0.07	—			
ACT-1078	Oshetna (informal)	mean	72.40	0.41	14.62	2.12[2]	—	0.63	2.26	4.38	2.73	0.21	—	98.38	10	Child et al. 1998
		1 σ	0.60	0.06	0.34	0.25	—	0.07	0.13	0.15	0.06	0.05	—			
ACT-1082-P1	Oshetna (informal)	mean	72.54	0.49	14.35	2.08[2]	—	0.71	2.41	4.19	2.77	0.21	—	95.16	17	Child et al. 1998
		1 σ	0.46	0.11	0.34	0.25	—	0.13	0.28	0.25	0.08	0.04	—			
ACT-1082-P2	Oshetna (informal)	mean	69.77	0.54	15.85	2.59[2]	—	0.91	3.10	4.29	2.45	0.22	—	96.76	9	Child et al. 1998
		1 σ	0.66	0.15	0.93	0.51	—	0.23	0.43	0.32	0.23	0.04	—			
ACT-004	Oshetna (informal)	mean	72.55	0.43	14.63	2.06[2]	—	0.66	2.31	4.20	2.72	0.21	—	97.79	22	Child et al. 1998
		1 σ	1.00	0.10	0.70	0.42	—	0.26	0.32	0.36	0.17	0.05	—			
ACT-4009 (P1?)	Oshetna (informal)	mean	72.55	0.28	14.67	1.62[2]	—	0.59	2.53	4.39	2.84	0.35	—	—	22	Personius et al. 2010
		1 σ	0.59	0.22	0.45	0.30	—	0.10	0.37	0.55	0.19	0.07	—			
ACT-4009 (P2?)	Oshetna (informal)	mean	69.61	0.56	15.53	2.37[2]	—	1.05	3.30	4.16	2.72	0.43	—	—	7	Personius et al. 2010
		1 σ	0.84	0.22	0.88	0.54	—	0.78	0.25	0.83	0.39	0.09	—			
Oshetna-P1	Oshetna tephra (informal)	mean	63.81	0.89	15.54	5.87[2]	—	1.99	4.97	4.30	1.77	0.21	—	96.87	—	Romick, 1984 (in Dilley 1988)
		1 σ	2.31	0.12	0.26	1.12	—	0.37	0.61	0.09	0.32	0.04	—			
Oshetna-P2	Oshetna tephra (informal)	mean	73.91	0.42	14.22	2.19[2]	—	0.54	2.18	3.65	2.43	0.21	—	—	—	Romick, 1984 (in Dilley 1988)
		1 σ	2.61	0.09	0.91	0.42	—	0.15	0.33	0.41	0.25	0.05				

Reported data represents weight percent average of n points, normalized to 100 percent.
—: not determined or not reported.
P: Population.
[1] Original analysis weight percent sum, prior to normalization.
[2] Fe reported as Fe_2O_3 and converted using the formula: normalized Fe_2O_3 * 0.8998.
[3] Jarvis Ash Bed is a formally defined stratigraphic unit (Péwé 1975), however, Jarvis Creek Ash is often used in publication to refer to the same unit.
[4] Secondary glass population; may not represent same tephra fall as the rest of Cantwell ash (Begét et al. 1991).
[5] May not represent same tephra as rest of Cantwell ash (Begét et al. 1991).
[6] Standard deviation published as “percentage of the reported value.”
[7]Original data was not normalized, but was normalized for comparison in this study.